The Engineer

APRIL 15, 1955 — 28, ESSEX ST., STRAND, LONDON, W.C.2. — TWO SHILLINGS

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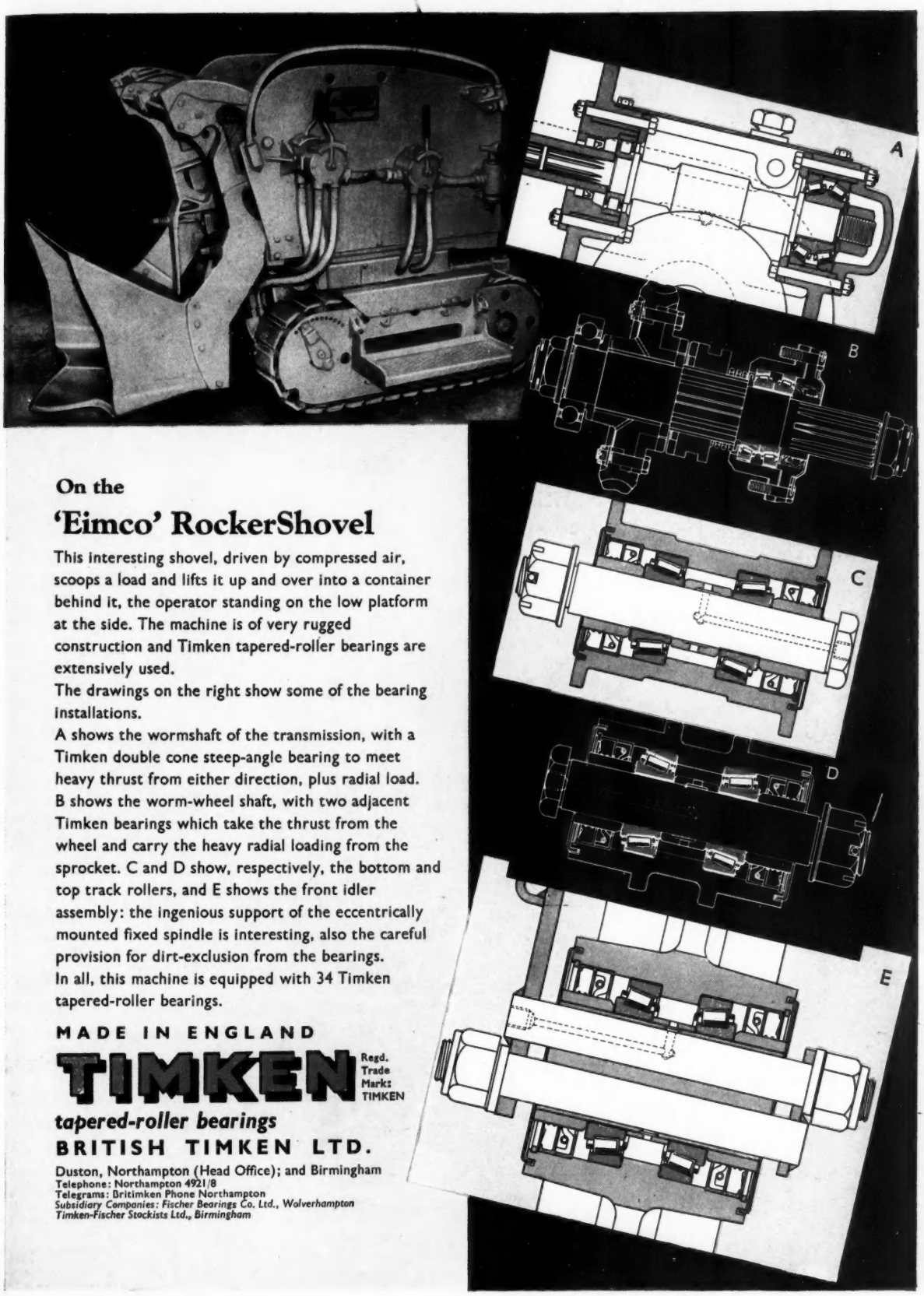

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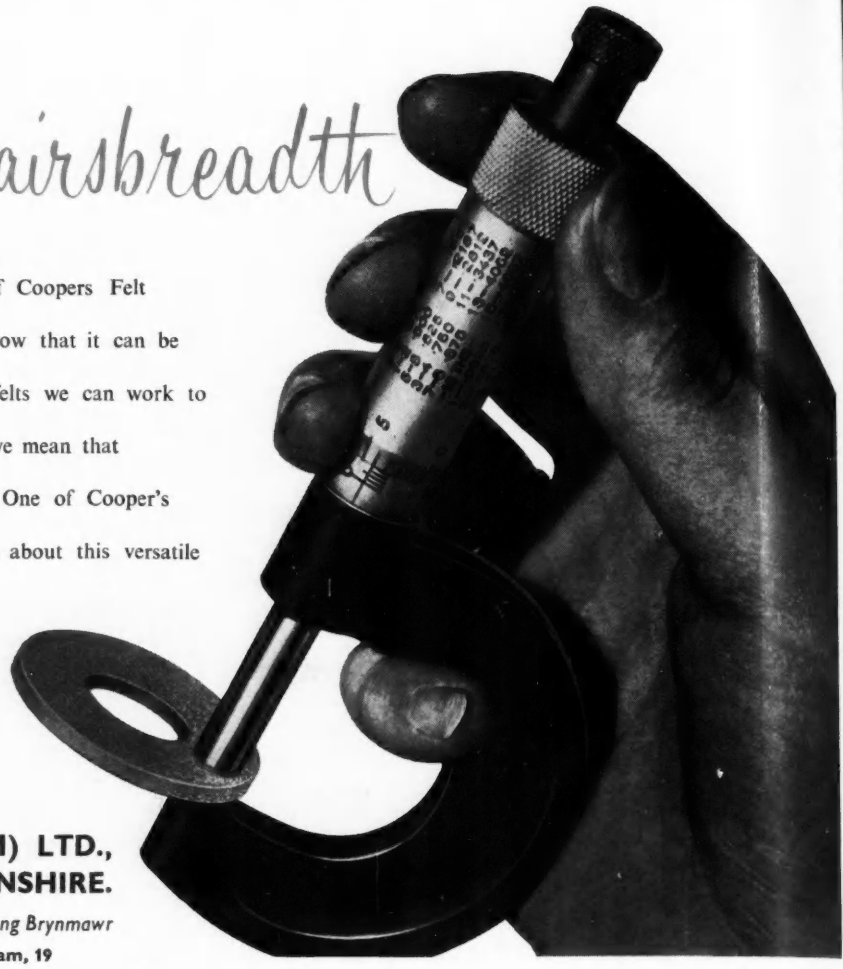

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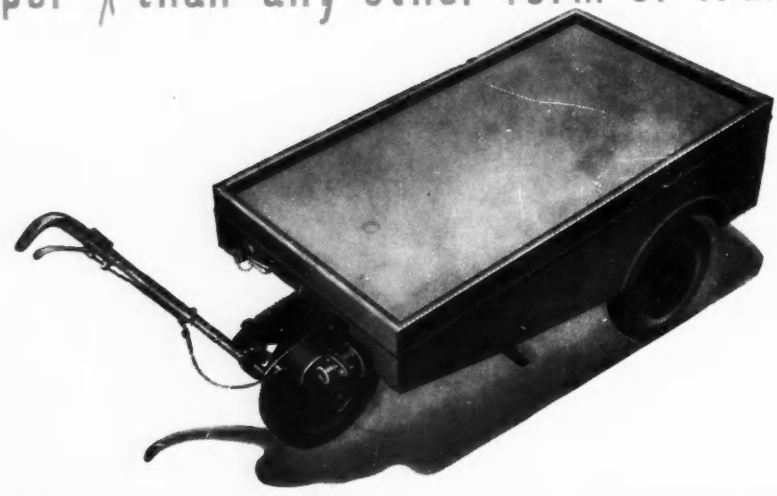

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THE ENGINEER

APRIL 15, 1955

Survey of Inland Waterways

THE Board of Survey of canals and inland waterways, which was appointed by the British Transport Commission last year, has now published its report. The Board was asked to find out whether the maximum economic advantage was being derived from the Commission's canal system, and what should be done about inland waterways which could no longer be put to economic use. Before preparing its report, the Board inspected most of the canals and obtained evidence from the bodies principally interested. The report states that from 1948, when the canals were taken over by the British Transport Commission, until 1953, well over £1,000,000 was spent on making good arrears of maintenance and another £500,000 on additional plant and equipment ; during that period, traffic increased by 30 per cent, from 10,000,000 tons a year to nearly 13,000,000 tons a year, and the Board remarks that the reduction of the deficit from £573,367 in 1951, to £102,060 in 1953, is evidence of improved efficiency ; it also remarks that a great deal has been done, with the finance available, to improve the system by dredging, piling of banks, improvements to towpaths, and so on. The Board's report recommends the establishment within the British Transport Commission of a separate organisation under a general manager to deal with waterways (this has already been done), and that certain docks should be under waterways administration. It also suggests that the Commission should concentrate its activities on waterways of real value and be relieved of the rest. Certain defined waterways, totalling 336 miles should be developed, it is stated, and a further 994 miles be retained for the present. The remaining 771 miles (which now involve a dead loss of about £200,000 per annum) are not considered to have sufficient commercial prospects to justify their retention for navigation. Canals in Scotland should be transferred to the Secretary of State for Scotland, the report recommends. It also states that the Government should be pressed to decide on the recommendations made in 1951 by the land drainage sub-committee of the Central Advisory Water Committee as to the future of waterways having insufficient commercial prospects to justify their retention for navigation.

Institution of Naval Architects' Annual Dinner

ON Wednesday, April 6th, the annual dinner of the Institution of Naval Architects was held at the Connaught Rooms, London, and was attended by about 1000 members and their guests, with Viscount Runciman of Doxford, the president, in the chair. The guest of honour was His Royal Highness the Duke of Edinburgh, and after the loyal toast the president gave the toast of " Our Guest of Honour," and said that it was his pleasant task to present the Duke with the Diploma of Honorary Membership, the highest honour which the Institution could bestow and one which was guarded jealously, there being only eight such members. Viscount Runciman recalled the long and continuous connection of the Institution with the Royal Family, and went on to say that His Royal Highness was welcomed equally as a member of that Family and as a seaman. In his reply accepting the Diploma, the Duke of Edinburgh also proposed the toast of " The Institution of Naval Architects." He acknowledged the contribution of naval architects to the art of shipbuilding and went on to mention the difficulties within the industry upon which the nation depends so much. In the field of design and research, he continued, the problem was how to combine the best of past experience with present possibilities and incorporate changes and improvements. The Duke raised the question of vibration and noted the recent advances in the efficiency of machinery and suggested that the next step was improved hull design. Mr. R. B. Shepheard, in proposing " The Guests," thanked the Duke for his presence and commented upon his stimulating interest in developments in this country. His Excellency the Portuguese Ambassador, Dr. P. T. Pereira, replied on behalf of the guests.

Uganda Electricity Board

A JOINT statement by the Uganda Government and the Uganda Electricity Board says that Sir Charles Westlake, chairman of the Uganda Electricity Board, is to retire on October 1st. Sir Charles, who is fifty-four, will have completed twenty-six years as a chief executive of electricity undertakings by the time he comes to leave Uganda. When he was only twenty-nine, he became the first county electrical engineer of Dumfriesshire and was responsible for the design of the Dumfriesshire electrification scheme. Two years later, he was appointed chief engineer and manager of the newly constituted Electricity Board for Northern Ireland. In 1936, Sir Charles became general manager of the Finchley Corporation electricity undertaking, and during his twelve years in that position he was elected to the council of the Institution of Electrical Engineers. In the last war, Sir Charles served on the " D " day planning staff, and later became chief fuel and power officer, North-West Europe. After the war, the Secretary of State for the Colonies appointed him to lead a mission to East Africa to report on electricity supply problems in the three territories. The mission's report was presented in September, 1946, and the following year, at the request of the Uganda Government, Sir Charles spent two months in the Protectorate preparing a detailed report on the power potential at Owen Falls, Jinja, and possible markets for electrical power. His report was unanimously adopted by the Uganda Legislative Council and Sir Charles was invited by the Government to become chairman of the Uganda Electricity Board. In 1949, Sir Charles was asked by the Government to set up a cement industry at Toronto ; he served as chairman of that industry's board until 1951. He also served for a time on the Board of the Uganda Development Corporation and two of its subsidiaries. It will be recalled that Sir Charles received the honour of knighthood last year during the visit of Her Majesty The Queen to Uganda to inaugurate the Owen Falls scheme. Sir Charles is to be succeeded as chairman of the Board by Mr. W. D. D. Fenton, the present deputy-chairman.

Lubrication of Tractors

AT a recent meeting in London of the Institution of British Agricultural Engineers, Mr. E. S. Bates presented a paper entitled " Technical Developments in the Lubrication of Tractors." In his paper, Mr. Bates pointed out that the lubrication of farm tractors involved greases, transmission oils, hydraulic oils, air filter oils and crankcase oils, and said that the mechanical development of the tractor in recent years had thrown more emphasis on the crankcase oils than on any of the others mentioned. Whilst there had been important developments in the quality of greases and transmission oils for automotive purposes, the design of tractor transmissions had altered so little that comparable developments in the lubricants had not been needed. Mr. Bates asserted that a degree of confusion existed in the grades and kinds of lubricating oil required for the farm that had more than one class of power and more than one make of tractor. The same kind of power producer, in the hands of different manufacturers, apparently required different viscosity grades. Changes of S.A.E. grades, Mr. Bates observed, were recommended as between winter and summer use, and there were variations in these recommendations as between one manufacturer and another. On a fully mechanised farm this could result in many grades of oil being carried throughout the year, and as the majority of oils were put up in 40-gallon barrels, a number of them were retained partly depleted. Future developments, Mr. Bates said, could do much to straighten out this confusion. There was no reason, he suggested, why vaporising oil, spark ignition and diesel engines should not use the same quality of oil.

Catalogue of Early Motor Vehicles

THE Veteran Car Club of Great Britain has compiled a catalogue of early motor vehicles which are preserved in public museums, in the collections of motor manufacturers and traders, and in the larger private collections in the United Kingdom. The catalogue, which is believed to be the first of its kind, gives particulars of about sixty vehicles housed in fifteen public museums, of eighty vehicles in twenty-one trade collections, and of about 150 vehicles in five private collections. Nearly all the vehicles are earlier than 1917, and in each case brief particulars are given, including the actual date of manufacture, the date of registration and the engine and chassis numbers. Among the many interesting items noted in the catalogue are portions of a very early steam coach or tractor, possibly a twin-cylinder Gurney of about 1830. The engine and part of the frame and steering gear are preserved in the Kelvingrove Park Museum, Glasgow. There are also references to the Grenville steam carriage of 1875, which is probably the oldest vehicle in running order in this country ; the Bremer petrol car, which is believed to have made its first run in 1892, and a three-cylinder Rolls-Royce of 1905, with open body. The catalogue is inserted in a loose leaf cover to facilitate the addition of extra pages. It is priced at 7s. 6d., and can be obtained from the Veteran Car Club of Great Britain, 46, North Row, Oxford Street, London, W.1.

Spraying Machinery for the Colonies

LAST week we visited the " Colonial Spraying Machinery Pool," which has been established at the Imperial College of Science and Technology Field Station, at Silwood Park, Sunninghill, Berkshire. This machinery pool is the result of collaboration between the Imperial College, the Colonial Office, the Ministry of Agriculture, and the Agricultural Engineers' Association, the aim being to provide facilities for training in the use of machines best suited for the application of pesticides to various crops in colonial territories, and particularly in underdeveloped territories. At present, the scheme is very much in its initial stage, but as was pointed out during the tour of inspection, much of the benefit of effective pesticides can be lost unless there is effective machinery for applying them. Arrangements already exist for careful study of the insecticides necessary for dealing with different pests in colonial territories, but so far there have been few facilities for plant biologists and chemists to collaborate with engineers in solving problems concerned with spraying. Mr. A. E. H. Higgins is in charge of the pool, and has been largely responsible for the collection of power and hand-operated spraying equipment assembled there. Short study courses are to be organised for Colonial Service personnel who are engaged in public health work or agriculture, and it is hoped that the establishment will also be available for demonstrating new developments in spraying machinery suitable for use in overseas countries.

Damodar Valley Project

BY OUR INDIAN CORRESPONDENT

No. III—(*Concluded from page 476, April 8th*)

Considerable interest has been aroused by the progress of the Damodar Valley Corporation's development schemes. The first stage of development is due to be completed in 1957 *; it involves* 300*MW of electrical power, a million acres of irrigation, about* 100,000 *acres of land reclamation, and navigational facilities.*

MAITHON and Panchet Hill dams together control a catchment of 6664 square miles out of the total of 7690 square miles above Rhondia, or about 86 per cent of the total drainage area. These two dams will intercept all floods originating in the Barakar and Damodar catchments, and hence they have been allotted the main function of flood control.[2] The obvious flood control strategy is to block separately the flood wave of the Barakar at Maithon and the Damodar at Panchet Hill, thus preventing their synchronism below the confluence of the two rivers. The worst affected areas lie in the flood plain below Rhondia, where the capacity of the channel is about 200,000 cusecs, almost a fifth of the maximum designed flood. It is proposed to increase this figure by 50,000 cusecs which, it is calculated, will be adequate to take the combined regulated flows from the two dams. During the dry season water stored in these reservoirs will be released for power and irrigation.

Maithon is one of the biggest dams under the scheme and its construction probably the most highly mechanised of all similar projects in the valley. The project[1] consists of (1) an earth dam about 160ft high by 2200ft long ; (2) a gravity concrete spillway about 600ft long flanked by concrete non-overflow sections 670ft long ; (3) earth dykes about 50ft and 30ft high and approximately 7000ft and 2000ft long on right and left banks respectively. The project is estimated to cost Rs.14 crores (£10·5 million) and some of the quantities involved are 2·6 million cubic yards of excavation (common), 1,000,000 cubic yards of rock excavation (open cut), 60,000 cubic yards of excavation in tunnels, 4·1 million cubic yards of rolled fill, over 500,000 cubic yards of concrete and about 2000 tons of steel. Construction on the main earth dam began in December, 1952, and is now over three-quarters complete. Concreting did not begin until after the diversion of waters in 1953 and so far just over 100,000 cubic yards have been placed.[3]

The main earth dam is a zonal embankment 32ft wide at the top and 1031ft wide at the river bed level (Fig. 11), with a maximum height of 162ft. The main body of the dam consists of a central core of selected impervious material, and shoulder fill on either side of it containing pervious, semi-pervious and impervious material. A blanket 20ft thick on the upstream side, a filter of dumped rock on the downstream side and a single sheet-pile cut-off wall 1040ft long in the central core portion are the other important features of the dam. Piles have been driven to a maximum depth of about 75ft. The embankment does not go down to solid foundation in the bed of the river. Suitable impervious spoil from the excavation works is laid directly on the sandy bed. Most of the work is done mechanically and the list of machinery on site is impressive by Indian standards. There are fourteen shovels, three with dragline and one with crane attachments, six truck cranes, twenty-six tractors, thirty-six dumpers, four graders, six rollers, two disc harrows, sixteen compressors and pile-driving equipment. The work is done departmentally. The concreting plant is also fully mechanised and has a capacity of 4000 cubic yards per day, one of the biggest in India (Fig. 12).

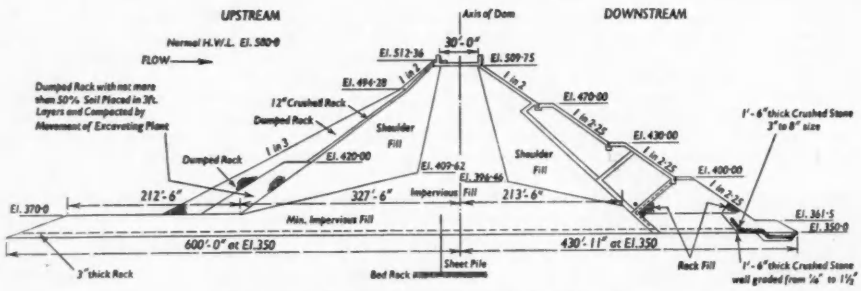

Fig. 11—Typical section on river bed of Maithon dam

The spillway is designed for a discharge of 510,000 cusecs, and in addition two sluices will dispose of 82,000 cusecs. Also, to ensure the safety of the structure, it being an earthen dam, an emergency spillway is incorporated in the design. The spillway is fitted with twelve sector gates 41ft wide by 40ft high. The total storage at the top of the gates is 1·1 million acre-feet, of which 725,000 acre-feet will be controlled flood storage. The average tail-water level is 150ft below the crest of the gates, the maximum gross head at the turbines being 154ft. The underground power house, details of which are now being worked out, will have three generators of 20MW each.

Panchet Hill Dam

In design, Panchet Hill dam is similar to Maithon, and while 100 million kWh of energy will be generated from its 40MW plant, the area it will serve with perennial irrigation will be 680,000 acres, as against 270,000 acres from Maithon (see Table IV for a statistical summary of the two projects). The dam, work on which has just begun, will be 135ft high, impounding a reservoir with a maximum storage of 1·2 million acre-feet, of which 881,000 acre-feet will be controlled flood storage. The concrete spillway is 775ft long with 200ft concrete abutments on either side. The main earth dam is 1800ft long and the earth dykes about ten times as long. Work on the diversion cut has already begun but the project will not get into stride

TABLE IV—*Maithon and Panchet Hill Projects Data*

	Maithon dam	Panchet Hill dam
Catchment, square miles	2,430	4,234
Flow :		
Maximum, cusecs	250,000	600,000
Average, cusecs	3,600	7,000
Minimum, cusecs	Nil	Nil
Dam :		
Height, feet	162	135
Length :		
Concrete portion, feet	1,300	1,175
Earth portion, feet	2,005	1,800
Earth dykes, feet	7,761	18,000
Reservoir :		
Storage (total), acre-feet	1,104,000	1,214,000
Controlled flood storage acre-feet	440,000	881,000
Live storage, acre-feet	496,000	185,000
Power plant :		
Maximum head, feet	154	120
Minimum head, feet	85	67
Normal head, feet	110	85
Installed capacity, MW	60	40
Benefits :		
Perennial irrigation, acres	270,000	683,850
Total power, kWh per year	164,000,000	100,000,000

Fig. 12—Batching plant at Maithon

until after the release of machinery from Maithon. The total volume of concrete has been estimated at 360,560 cubic yards, of which less than a third had been laid by the end of 1954. The earth section is proceeding a little faster and of the total volume of rolled earth of 5,344,000 cubic yards, more than half had been placed and rolled by December, 1954. The dam may be completed by 1956, but the power house, which is still in the design stage, may not start functioning until at least a year later.

Durgapur Barrage

The Durgapur barrage acts as the main headworks for the whole of the Damodar irrigation system, controlling a network of canals and distributaries irrigating over 1,000,000 acres of land.[2] The barrage will also act as the controlling reservoir for the navigation canal. Durgapur is about 40 miles below the confluence of the Damodar with the Barakar ; there will be two main canals, the one on the left also serving as a navigation canal providing transport facilities for small river craft between Calcutta and the coal mining areas near Raniganj, and the one on the right for irrigation only. The barrage has been designed for a maximum discharge capacity of 550,000 cusecs, since the maximum design flood of 1,000,000 assumed as likely in the upper reaches is expected to be moderated by the four dams on the two rivers.[4]

The barrage (Fig. 13) consists of thirty-four bays, each 60ft wide, of which twenty-four bays will constitute the main weir, and five on either side will have under-sluices discharging into the main canals. The total length of the barrage will be 2271ft, and it is about 35ft high above the river bed. The piers are in concrete faced with precast concrete blocks. The floor has been designed as a continuous reinforced concrete raft supported on piers 7ft wide spaced 60ft apart. At the middle of each span a groyne is provided to add extra weight against uplift pressure. Three rows of sheet-pile cut-offs, one each at the toes of upstream and downstream glacis and one at the extremity of the downstream horizontal floor, have been provided to depths sufficiently in excess of theoretical scour depths. The downstream side is protected by a length of graded inverted filter next to the impervious floor and beyond that by a length of concrete blocks and loose stone pitching. The upstream side is protected by concrete blocks and stone pitching only. Two rows of friction blocks, one at the toe of the downstream glacis and the other at the extremity of the downstream horizontal raft, are provided for energy dissipation. There are also silt excluders. The general approach to the problem of energy dissipation and the consequent design of the works is in line with the accepted Indian practice of weir design. It is, however, probably for the first time that concrete, not a conventional building material in India, is being used in such large quantities. Most existing weirs in India are of masonry construction.

Table V

Durgapur barrage :	
Length, feet	2,271
Height, feet	35
Design discharge, cusecs	550,000
Submerged area, acres	3,200
Canal system :	
Left bank :	
Discharge at head, cusecs	9,200
Width, feet	172
Depth of water :	
Maximum, feet	12
Average, feet	8
Right bank :	
Discharge at head, cusecs	2,271
Width, feet	59
Depth of water :	
Average, feet	9
Length :	
Main canals, miles	140
Branch canals, miles	250
Distributaries, miles	799
Drainage channels, miles	374
Total length of the system, miles	1,563
Benefits :	
Irrigable area, acres	1,025,762
Yield of food :	
Rice, tons	350,000
Straw, tons	650,000
Navigation traffic :	
Coal, tons	1,500,000
Miscellaneous, tons	500,000

There are two head regulators. The head regulator for the main left bank canal will consist of eight spans of 20ft each with piers 5ft wide. The width of the canal at the head reach is 172ft at bed level, and the depth of water at full supply level will be 12ft, the minimum normally being 8ft, adequate for barges up to 6ft draught. The right bank head regulator is smaller, having only two spans of 20ft each with one pier in between. The width of the canal at head reach is 59ft and depth at full supply level will be 9ft. This canal is for irrigation only.

Work on the barrage began in 1953 and the target date for completion is June, 1957, which is also the target date for all canals, distributaries and drainage channels, navigation locks on the left bank canal, falls and regulators, loading berths, bridges and culverts. The total length of canals is about 1180 miles, involving excavation of about 1650 million cubic feet of earthwork. The 90-mile long navigation canal is provided with twenty-two navigation locks and twenty-four loading berths ; the system as a whole includes the construction of 634 falls and regulators, 673 bridges and culverts and thirty-nine railway bridges. At the end of 1954 about a fifth of the work was completed.[5] Table V gives a statistical summary.

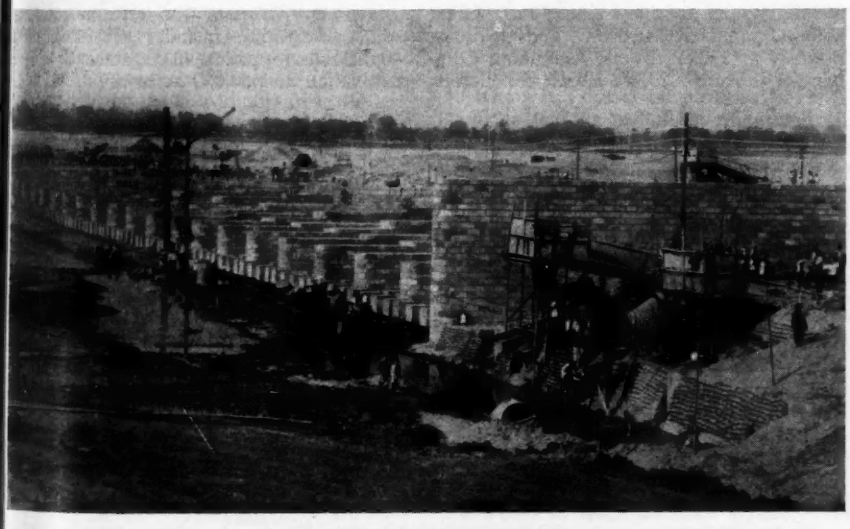

Fig. 13—Durgapur barrage under construction

Power Demands

The operational phase of the Damodar Valley project may be said to have virtually begun in January, 1952, when the distribution of power from Sindri on the D.V.C.'s grid commenced. The valley is probably the only one in India where supply will have a great difficulty in keeping up with the demand, for the valley is the most industrialised region in the country. According to an estimate of the Central Technical Power Board (to which reference has been made in the first article), the total installed generating capacity in the region is about 392MW, of which just under 270MW cater for industrial loads. Most of the current industrial power plant, however, is outdated, and only a portion would remain serviceable for regular supply of power after commencement of supply from the D.V.C. According to the report, "... in the case of town installations, the installed capacity has been found inadequate, conditions of plant unsatisfactory, and working uneconomical. Many of the colliery power stations are likely to close down gradually and the generating plant installed in the major industries is not capable of coping with the increasing demand on the expansion of industries." As a result of the load survey, the total potential maximum demand on the D.V.C. grid was assessed at 282MW, 459MW and 555MW, respectively, during the next five, ten and fifteen years. In the first phase of development, in which greater stress is being laid on flood-routing and irrigation, it may not be possible to reach all the loads. Accordingly, for the present, only those loads have been taken into account which can be conveniently catered for in the first phase (Fig. 14). The initial power installations, aggregating 294MW of installed capacity, are made up of 150MW from Bokaro thermal power station,[8] and 144MW from hydro installations covering Konar (40MW), Maithon (60MW), Tilaiya (4MW) and Panchet Hill (40MW). From the progress report for the year ended July, 1954,[9] it appears that the first stage of power development will not be complete until well after 1957. It may then be able to supply about 1000 million kWh per year.

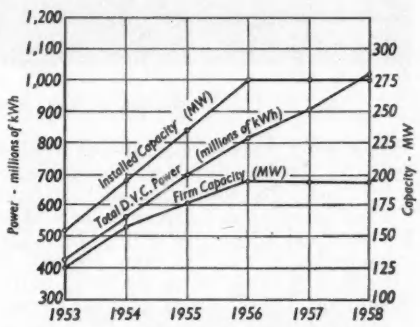

Fig. 14—Growth of capacity and load in the D.V.C. power system

Transmission System

When all the power stations in the first stage are completed, the transmission system will make available 1500 million kWh of energy per annum over an area of 35,000 square miles. The grid system (see Fig. 1, *ante*), will comprise 375 miles of 132kV double-circuit main transmission lines, 96

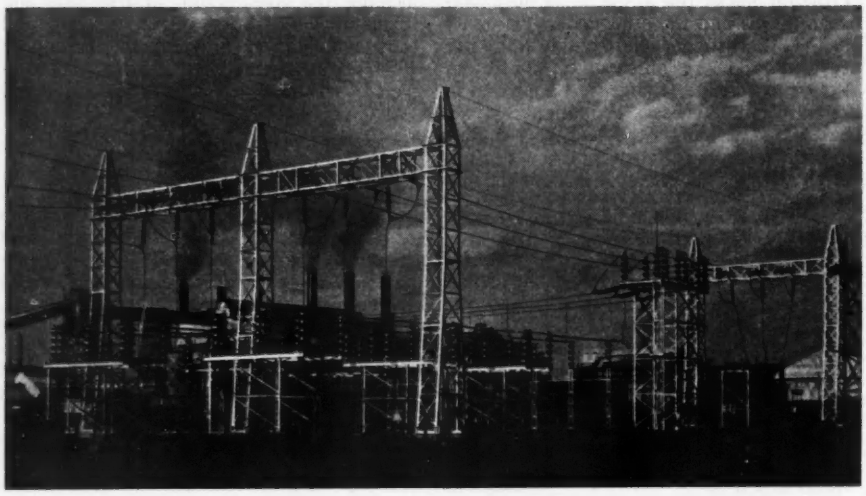

Fig. 15—D.V.C. substation at Sindri with the Sindri power station in the background

miles of 33kV double-circuit sub-transmission lines and 32 miles of 66kV single-circuit temporary lines.[7] This will connect all the stations and will extend from Ramgarh in the west to Burdwan and Kharagpur in the west. The transmission system has been planned to serve existing industries in the valley in the initial stage, and the design is flexible enough to cater for future expansion. There are, in all, fifteen 132kV substations, five 66kV and fourteen 33kV receiving stations. By the end of last year, 300 miles of 132kV line had been completed along with the whole of the 66kV and 33kV lines. Bokaro has now been connected to Maithon via Loyabad and Sindri (Fig. 15) and Jamshedpur in the far south has also been linked with Bokaro, via Gola. The Tata Iron and Steel Company, at Jamshedpur, has in hand its own 6·6kV transmission system, including three receiving stations, of which two have been completed and the third one should be ready before monsoon. This is the first big load to be supplied by the D.V.C. outside the valley limits, although it had earlier made a big start by supplying power to the Chittaranjan Locomotive Works, the Indian and Iron and Steel Company, at Kulti, and a few electric supply companies in the nearby districts. The sale of D.V.C. power during 1953 amounted to 109·5 million kWh, and the figure for 1954 is expected to be nearly double.[9] Steps are being taken to meet further demands. The transmission system is being extended to Calcutta at one end, and Gaya, Patna and Dalmianagar at the other. An agreement was recently entered into with the Government of West Bengal for electrification of the Calcutta suburban railways, and the Calcutta Electric Supply Corporation have undertaken to buy power from the D.V.C. to the extent of 45MVA, rising in five years to 100MVA. Completion of the system is scheduled for the middle of 1957.

A typical 132kV transposition tower is illustrated in Fig. 17. It is of latticed steel construction, suitable for double circuit with one earth wire on top. The overall height of the tower is 90ft, the area at the base is 13 square feet, and that at cross-arm level 5 square feet. For normal towers, three equal cross-arms are provided which allow a horizontal conductor spacing of 23ft. For 33kV distribution, locally-fabricated H-shaped structures made of rail are being used. They are about 34ft high, the vertical distance between cross-arms being 4ft and horizontal distance between conductors 8ft.

Based upon the design load for the ultimate development, the 132kV line has been provided with 37/·1151in steel-cored aluminium conductors (aluminium 30/·1151in), equivalent to 0·2 square inch copper. Brief particulars of the conductors are : overall diameter 0·806in ; ultimate strength, 20,000 lb ; maximum design working tension at 35 deg. Fah., 8000 lb at 2·5 factor of safety ; maximum sag in still air at 140 deg. Fah., 22ft. On the 33kV distribution line a 7/·1878in conductor is used.

The 132kV line is carried by standard suspension insulators 10in in diameter, made of nine discs for a normal suspension string and ten discs for the corresponding strain type. The flashover voltages for a nine-disc unit at 60 c/s is 540kV dry and 375kV wet. The corresponding figures for a ten-disc insulator are 590kV and 415kV respectively. The 33kV insulators are of three-shell pin type, 14in high, with dry and wet flashover voltages of 145kV and 100kV respectively.

To maintain stability in the power system the line circuit breakers are provided with high-speed reclosing, overload, reactance, impedance, carrier relays. Carrier current relaying is an important feature of the grid. The intercommunication will be through very high frequency radio communication. This grid will have a central load-dispatching station at Bokaro to facilitate economic transmission. Various circuit breakers (bulk oil, minimum oil, and air blast) are used in the grid.

Manufacturers supplying major equipment for the system are Blaw-Knox, Ltd., Great Britain, and Richardson and Crudas, Bombay ; 132kV towers, Aluminum Company of Canada ; 132kV a.c.s.r. conductors, Locke Insulators Corporation, United States, and Nippon Gaishi Kaisha ; 132kV line insulators, Oerlikon Company, Switzerland ; minimum oil circuit breakers, the British Thomson-Houston Company, Ltd., Great Britain ; 132kV bulk oil circuit breakers and power transformers from Hackbridge and Hewittic, Ltd., Ferranti, Ltd., the British Thomson-Houston Company, Ltd., and English Electric Company, Ltd., Great Britain.

Reclamation and Conservation

Power production is only a subsidiary D.V.C. activity ; the Corporation is primarily concerned with the prevention of floods in the valley and irrigation. For instance, in terms of cash, the extra food is computed at Rs.30·45 crores (£22·5 million approximately), the extra jute at Rs. 3·6 crores, and the power at Rs. 4·18 crores.[9] The revenue from power will thus be about one-tenth of the total revenue accruing from other activities. The emphasis on food production and soil conservation is reflected in the amount of effort that is now being made for reclamation of land, rehabilitation of displaced people and water management on a rational basis. This programme, it is said, will not only lead to greater yield of food, but also retard the silting of major reservoirs and thereby add indirectly to the life of the power system.

The basis for the programme of land reclamation is very simple.[5, 6] The upper valley of the Damodar covers about 4·4 million acres, containing approximately 1,000,000 acres of waste land, including 200,000 acres classified as forests which have nearly disappeared. On these areas, both Nature and man have wrought such a havoc that they are no longer suitable for cultivation : the erosion has made such a progress that only 350,000 acres can be reclaimed for cultivation and about 50,000 reafforested or put under pasture. This is less than 10 per cent of the entire head waters region, and according to a report,[5] "its immediate reclamation is essential not merely because soil erosion and water losses are worse here than elsewhere, but also because from this foci, contagion, as it were, is spreading fast to land still under cultivation or forest." Moreover, it has been found that economic conditions for large-scale reclamation are exceptionally favourable in the valley. The average cost of reclamation for "paddy terraces," for example, is about Rs. 550 per acre as compared with Rs. 630 for the existing similar land in the locality.

The D.V.C. plan for reclamation and soil conservation includes reclamation of 40,000 acres for paddy, 40,000 acres for upland cultivation and 50,000 acres of forest. The

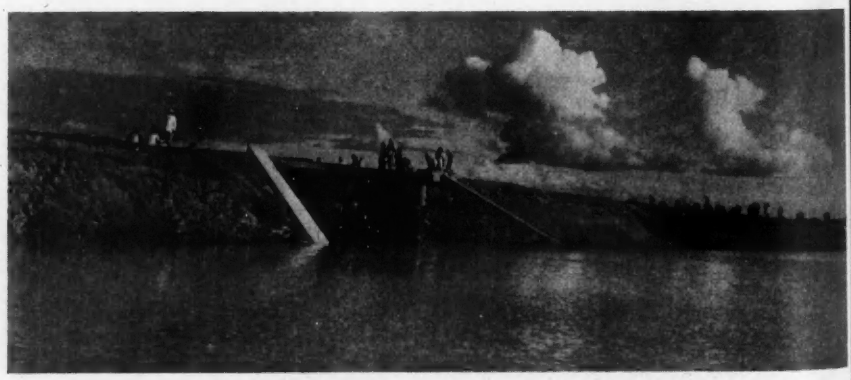

Fig. 16—Gauria-Karma dam. One of the small dams for irrigation of newly reclaimed fields as part of the Damodar Valley Corporation's headwaters control programme

plan also includes a programme of complete detailed air survey and mapping, land use and forest surveys of the whole upper valley, the establishment of four experimental stations, fisheries, and a number of experimental farms. A scheme for building small dams in the head waters of the river system (Fig. 16) was put into operation as far back

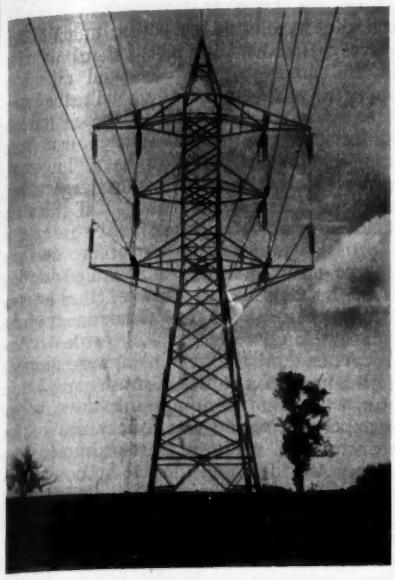

Fig. 17—A typical transposition tower for 132kV transmission line

as 1949, and six such dams have already been built—four in the areas where people displaced by Tilaiya reservoir have been resettled and two in the neighbourhood of Hazaribagh. The programme is now more than halfway through and is expected to cost over Rs. 8 crores (£6,000,000). Most of the contour bunding and other reclamation work is being done mechanically and the capital expenditure on the machinery has been well over £1,000,000. The work is spread over an area of about 4000 square miles.

Another problem which the D.V.C. has been called upon to tackle is that of rehabilitation of people displaced by the reservoirs. The first phase will displace about 75,000 people and submerge about 72,000 acres of land and over 5000 houses. The writer toured the valley last year and was struck by the success of the rehabilitation schemes in the Tilaiya area. Brand new villages have been constructed where nothing existed before and at many places the emphasis has been on the co-operative aspect of the programme. Cottage industries will form an important feature of the economy of these villages for which cheap power will be made available from the grid. In effect, new life is returning to these communities which only four or five years ago had to eke out a bare living on the waste land of the upper valley. The rehabilitation and resettlement programme will keep pace with the submergence of lands as the reservoirs get filled and the first phase should be completed by the end of 1958.

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Applied Mechanics

No. II—(*Continued from page 494, April 8th*)

At a meeting of the Institution of Mechanical Engineers, which began after lunch on April 1st and continued into the evening, a number of papers were read and discussed. The meeting was organised by the Applied Mechanics Group and we here print summaries of the papers and abstracts from the discussions.

THE second paper presented at the meeting of the Institution of Mechanical Engineers on April 1st was:

PREDICTION AND MEASUREMENT OF VIBRATION IN MARINE GEARED-SHAFT SYSTEMS.

By the late H. G. YATES, M.A.*

In a classic paper on torsional vibration in branched systems, Smith (1922)† surprised and almost frightened many marine engineers by pointing out with lucid mathematics the infinite series of critical speeds which can theoretically occur in such systems, and advocated the "nodal drive" as a means of greatly reducing the number which might be experienced in the operating range of speed. Although several contributors to the discussion of his paper adopted a more realistic point of view, and remarked that many of the critical speeds, though theoretically possible, were not serious in their effects, nevertheless, the unpleasant possibilities so influenced many designers and shipowners that the development of double-reduction gearing in Britain was held back for nearly twenty years. When beginning to undertake the design of reduction gearing in 1945, the present author felt the need for a reliable method of predicting shaft vibration which would enable not only critical frequencies but also vibration amplitudes to be estimated for any given stimulus, and which, furthermore, would do so without requiring an inordinate amount of calculation work. With the valuable assistance of his colleagues, and by employing the instruments and research facilities built up at Pametrada Research Station during the past eight years, a method has been developed which, he suggests, meets the requirements with all reasonable completeness.

This method is equally applicable to both of the two main kinds of stimulus which induce torsional vibration in geared-shaft systems, namely, force excitation, as by periodic hydraulic forces acting on the propeller, and displacement excitation, as by errors in the cutting of gears or toothed couplings which cause periodic variations in the velocity ratio of mating components. The former kind of stimulus has its greatest effect when acting at the free end of a shaft, where a finite amplitude of vibration enables the exciting force to perform work on the system and so maintain the vibration. The second kind of stimulus is most effective near a node: in this position small errors can give rise to large vibrating torques, as will be seen.

DISCUSSION

Professor D. G. Christopherson: I do not want to say more about the method of calculation which takes up the first part of the paper than simply that I think it is a most impressive example of the advantages of this kind of method of calculation in actual practice. I think perhaps that mechanical engineers on the whole have been too slow to take a leaf out of the electrical engineer's book in making use of the admittance and impedance method. I think that this paper is an excellent example of the very great advantages which can be derived from it. The whole difficulty of this problem from the point of view of theory is the question of what one should assume for the damping factors. In the paper it is stated that on the gear and turbine side there is a discrepancy of about a factor of 10 between the damping factor that can be expected on the basis of knowledge about hydrodynamics of the turbine side and the damping factor that is in fact encountered. We have been told that it was Mr. Yates' opinion that the greater part of this was the damping which arose due to the variable loads on the gear bearings. I have no direct experience in this field, but it seems to me that there are some other sources of damping which may be coming in and which may be quite important. First of all, it seems to me there is a possibility that there is a good deal of damping at the points of contact of the gears themselves. When torsional vibration is taking place in bad cases with actual separation of the gears and in less severe cases with very large variations of the load, it seems to me that this must be a substantial source of damping. There is also the fact that presumably in cases where torsional vibration is taking place some energy is all the time being communicated to the surrounding structures. That is how we know in a sense that torsional vibration is taking place—it being communicated to different parts of the ship. It seems to me that this is really the centre of this problem. If we knew what was happening beyond all this energy, we should be safe in making, where necessary, fundamental changes in design. It may be, however, that if we make some change and we do not understand sufficiently the damping question, that change will have an effect on the bearing which we have not been able to predict.

Professor W. A. Tuplin: I am afraid I do not agree with some of the things which Mr. Yates has said or, incidentally, with some of Professor Christopherson's later remarks. The electrical analogy for mechanical vibrating systems is academically attractive, but of no help to the mechanical engineer unless he is thinking of making an electrical model of the system as a cheap alternative to a mechanical one. It does not seem to me that the mechanical engineer could understand any better what inertia is by saying it is an analogy of inductance. On the contrary, my own experience of the electrical system went in quite the opposite direction. I was able to understand more clearly what inductance was by saying it was analogous to inertia!

Mr. S. Archer: Within the past fifteen years or so the double reduction marine gear may be said to have entered into its own again after a considerable period in the wilderness, at least in this country. To-day, it may justly be claimed that in comparison with the dark period of the early 1920s its prospects of reliable service are vastly improved. This is mainly a result of the great advances in gear metrology and gear-cutting accuracy, the introduction of post-hobbing processes such as shaving and grinding and the use of improved materials. Some of the credit may also legitimately be ascribed to the application of quill shafts in the articulated form of drive which is so popular to-day, especially in the United States and increasingly so in this country. Nevertheless, excessive tooth wear and even breakage are occasionally reported and there is evidence to suggest that in some cases torsional vibration has been one of the factors responsible. This stimulating and helpful paper therefore holds a special appeal to marine turbine designers and vibration engineers alike. The methods of calculation advocated by Mr. Yates are not new in

* Mr. Yates, who died on September 15, 1954, was formerly chief designer, the Parsons and Marine Engineering Turbine Research and Development Association (Pametrada).

† An alphabetical list of references is given in Appendix III.

principle, but much credit is due to him for the deft manner in which he has succeeded in bringing theory down to earth, as it were, in a practical attack on the problem.

In his introductory remarks Mr. Yates rather suggests that it was Mr. Smith with his nodal drives and critical speed bogey who was mainly responsible. for scaring British owners away from the double reduction gear in the early 1920s. It would, I think, be fairer to ascribe the cause to the many failures in this type of gear at that time, which was undoubtedly in most cases a result of sheer bad gear cutting—as judged by present-day standards—and among those who first pointed this out was Sir Henry Guy, our former secretary, who drew attention to the very high inertia loading which could be caused at high pitch line speeds by quite small hobbing errors.

It would seem that until such time as propeller excitation factors and damping factors for turbines and gearing are more firmly established, there is little justification for the use of such refined methods of calculation as advocated by Mr. Yates, except where two critical speeds are in close proximity, and also for the calculation of vibration torques due to displacement excitation from gearing errors. For the latter case Manley's dynamic stiffness t/θ method is probably equally convenient and perhaps more easily grasped by mechanical engineers.

From evidence provided by some 150 calculations of geared turbine systems carried out at Lloyd's Register of Shipping using the critical excitation method advocated by Bassett and Powell (which is, of course, substantially an energy method) there would certainly seem to be some justification for an increase in turbine and gearing damping factors ; but whether Mr. Yates's Q value of 20 is appropriate or not remains to be investigated.

Professor B. J. Terrell : Two main points have arisen from the discussion, and one was the old horse of electrical energy versus mechanical calculation. I can only state a personal opinion. I think the impedance method is very much more simple and quicker and it is the one which we use, but we can argue about that in the written discussion.

The other question was that of where the damping comes in. I will produce some figures, as requested, but I do not think the hysteresis is significant. Since the paper was written we have been collecting quite a bit of evidence on the effect of bearing damping with variation of load, which you get in gearing bearings. We have been doing it more particularly from a different point of view, the effect of bearing damping or the non-regularity of bearing resilience, one might call it, on the critical speed of high-speed turbine rotors. I think the two things will eventually tie up.

The following two papers were next presented.

THE PROMOTION OF FLUID LUBRICATION IN WIRE DRAWING.

By Professor D. G. Christopherson, O.B.E., Ph.D., B.A.,* and H. Naylor, B.Sc.†

One of the factors limiting the rate at which wire can be drawn through tungsten-carbide or diamond dies is the severe die wear which may occur at high speed. If true hydrodynamic (fluid film) lubrication could be provided in the die, wear would probably be much reduced. It is suggested that this can be done by supplying oil to the entry of the die at a pressure comparable with the yield stress of the wire. The necessary pressure can be conveniently generated by causing the wire to approach the die through a tube of diameter slightly larger than the wire diameter, sealed on to the inlet side of the die.

Experimental work shows that the friction in the die itself can then be so reduced that, even when the drag in the tube is allowed for, the total drawing force is less than with the existing method of soap lubrication ; and tests with steel dies have shown large reductions in wear.

A theory of the behaviour of the inlet tube and of temperature distribution in the system is included.

* Department of Mechanical Engineering, The University, Leeds.

† Research engineer, Shell Research, Ltd., Thornton Research Centre.

INVESTIGATION OF THE MECHANICS OF WIRE DRAWING.

By J. G. Wistreich, M.Sc. (Eng.)‡

Round wire was drawn slowly and without back-pull through dies with bores in the shape of truncated cones, in a study of the relations between external forces and process parameters. Not only the drawing force but also the mean die pressure and the mean coefficient of friction were measured, so that existing theories of wire drawing could be put to a more exacting test than had hitherto been possible. The investigation has revealed weaknesses in all wire-drawing theories ; the use of Hill and Tupper's (1948) sheet-drawing theory for the prediction of forces in wire drawing is not justified. Semi-empirical formulæ for the forces have been devised. A simple relation between tool-stock configuration and non-homogeneity of deformation was discovered, which is also applicable to the mechanics of swaging. The assumption that the deformation is independent of the properties of the wire is not valid for annealed wires drawn with very light reductions, but is acceptable otherwise. The occurrence of thickening of the wire before entering the die and its continued thinning beyond the die deserves attention in bar drawing. There was no correlation between die pressure and coefficient of friction.

‡ Head of metal working laboratories, British Iron and Steel Research Association, Sheffield.

Discussion

Mr. G. D. S. MacLellan, M.A., Ph.D. (Pembroke College, Cambridge) : I hope that Professor Christopherson and Mr. Naylor's plea for the further development of their device will be acted upon, not because I any longer have an interest in any patent connected with the device, but for its own merits. In their reference to the contrivance which Cameron and I devised in 1943, we are reminded that our object was to encourage the formation of a fluid film in the die by ensuring the supply of oil at the die face under a pressure comparable to or greater than that in a high-pressure lubricating system. We feared, however, that our device might be choked by the accumulation of copper swarf at the die face, and my recollection is that this was a reason for our limited ambitions rather than the motive behind the construction of the device, as the authors have suggested. Owing to war circumstances, our experiments at that time were not carried far enough to lay low this bogey, nor to investigate the possibilities in the way that the author has since done.

Besides the general considerations which had led us at that time to seek to promote fluid film conditions, Eichinger and Lüg had published, in 1941, an account of an investigation of the heating of wire and die in cold drawing. This included a discussion of the characteristics of the fluid film which might be formed at the entrance to the die under appropriate conditions, including an allowance for the effect of pressure on oil viscosity. Their experiments were done at such slow speeds—about 30ft per minute—that it is doubtful whether they were achieving fluid lubrication. They deserve credit, however, for the first detailed discussion of the subject. The authors have rightly stressed the importance of limiting the wire surface temperature in wire drawing. In their analysis they have not, however, taken account of the temperature rise of the wire due to the work of deformation, nearly all of which will appear as thermal energy in the wire. It would be of interest to know whether the authors experienced any difficulties due to the formation of the swarf or copper dust, to which they have made some reference, and also whether vibration of the wire at entry to the tube was troublesome, especially if the level in the oil reservoir were permitted to get low. In some high-speed investigations carried out in 1943, we found it helpful in this connection to lead the wire to the tube through another die which constrained it but caused little or no reduction. In Mr. Wistreich's paper, it is of particular interest to learn that measurements with split dies have been the key to much of this success, after my own unsuccessful attempts in this direction. The essential difference appeared to be the use of a solid rather than a liquid lubricant. It would be of interest to learn whether Mr. Wistreich had done any experiments with oil as a lubricant, and also how he obtained the large differences in μ revealed in Table IX if the same solid lubricant was being used throughout the investigation. In view of the author's use of strain gauges to measure drawing force, I should like to know whether he considered their use for the measurement of the splitting force. If a split die with a cylindrical casing, slightly modified, were strapped with a metal top to which strain gauges were attached, from reading the two halves together one could use a measure of the reduction in strain in the resistance wire during the drawing to give a continuous measure of splitting force. This would have the additional advantage that one would not have to work from cold to a point at which the two halves of the die separate. There are two particularly striking features of the results to which I want to refer briefly. One is that the mean die pressure is higher than the mean yield stress of the wire for many combinations of reduction and die angle in common use. This, I think, emphasises the need for good lubrication as well as for adequate strength in the die wall. Very little attention has been given to this subject of the best way of reinforcing the carbide or diamond dies. The second feature is that at the end of a very extensive investigation, it can be said with little exaggeration that as far as estimation of the power requirements are concerned, we are almost exactly back at a result published forty years ago !

Mr. Wistreich : The two points which I want to make are, briefly, that Professor Christopherson's method does not constitute a break with normal wire drawing practice and that, for practical reasons, the method must be made to work with boundary-type lubricants, even though simple mineral oils are more convenient from the point of view of rational tube design. The reason I want to make those points is that I am particularly anxious to see this method accepted by industry quickly. I support Mr. MacLellan in his feelings, and I should like to give an assurance that a good deal to bring this about is being done.

I should like to show some evidence that conventional lubrication in wire drawing is not purely of the boundary-type as Professor Christopherson said in his introduction but, on the contrary, that it contains a significant hydrodynamic ingredient. [The speaker then showed some slides and discussed them.]

I hope I have shown enough in support of the argument that at speeds of industrial interest a significant hydrodynamic ingredient is present even in conventional wire-drawing lubrication. This argument in no way belittles the merits of the authors' work. It goes to show, however, that the difference between their scheme and conventional practice is one of degree. It suggests that industry is not forced either to adopt the new method in its entirety or otherwise reject it,

but it is free to move gradually, to improve lubrication by stages and, if need be, stop at a half-way house. Let me give a few reasons for which this cautious approach is desirable. The authors have rightly stressed that in wire drawing the chief purpose of lubrication is to reduce wear. Compared with wear, frictional drag is a minor nuisance. For this reason, the use of mineral oil is not, in general, to be recommended, however convenient it may be in affording a rational basis for tube design. With mineral oil, the wire and die are unprotected against wear during starting and stopping and at any time when drawing below a critical speed. Instead, I would advocate the use of protective coatings and of lubricants which are good also under conditions of boundary lubrication, for instance, water-soluble emulsions of polar lubricants. If such lubricants are used, then one can also relax requirements of tube design, such as tight clearance and correct alignment of longish tubes, which are not acceptable in industry for practical reasons, and this would outweigh even the advantages to which attention is drawn—improvement of heat transfer. This is the line of thought by which our development work is being guided. So far we have concentrated on the conversion of rolled rod into medium-sized wire, which is done at fairly slow speeds, and in this we used soap powder as a lubricant and a modified pressure-tube die assembly. I will not go into the details of the problems which we have had to overcome in devising a similar device for a material such as soap powder, which has different physical properties from oil. The point I want to stress is that our device is rapidly finding its way into industry and the results are remarkably good. To quote but a single example, we have recorded a fifteen-fold improvement in die performance on a modern production machine.

Mr. P. Grodzinski (Industrial Distributors (Sales), Ltd., Diamond Research Department): One problem which has intrigued me for some time is that of an optimum angle. O. Herrmann developed the optimum reduction angles for cross-sectional reductions from 0·5 per cent to 30 per cent and friction coefficients from 0·01 to 0·09. But already the different formulæ developed by Wistreich show that not too much confidence should be placed in such derivations, and I should like to ask the author whether he thinks that practical use can be made of this relation. I would rather see experimental values for different conditions of dies and materials drawn. Apparently Mr. Wistreich has covered only drawing of copper wire and most probably has used sintered carbide dies, but no information on this is given in the paper. In practice, however, a whole range of metals and alloys has to be drawn through steel, sintered carbide and diamond dies, and I personally believe that not only the reduction and the coefficient of friction will determine the optimum die angle. The optimum die angle as discussed before has been developed from the point of view of minimum die pull, leading to a minimum power consumption. A number of years ago I advanced a suggestion to consider not only the die angle and the reduction but also the relative length of contact between wire and die in the reduction zone as this will influence the life of the die. This theory, without any further comment, has recently been published in a Czech journal and E. Siebel has referred to it in some of his publications, but so far I am not aware of any experimental work in this direction, which was the purpose of this suggestion.

Dr. G. W. Rowe (Research Laboratory on the Physics and Chemistry of Surfaces, the University, Cambridge): One of the important conclusions which follows from Mr. Wistreich's paper is the inadequacy of existing plasticity theories of wire drawing. Thus, the classical treatment for two-dimensional deformation derived by Hill and Tupper gives poor quantitative agreement for the axially symmetrical problem involved in wire drawing. It seems to me that one of the major difficulties in all such theories is the assumption that the coefficient of friction between the wire and the die is a single valued constant. The conditions in the lubricant film are very complex indeed and the properties of the film may be greatly influenced by the high pressures to which it is subjected in the die.

For this reason, I wonder whether the conventional laws of friction can be validly applied under the conditions operating. I should like to ask, therefore, whether Mr. Wistreich has considered carrying out a simple low-speed drawing experiment in which the wire is coated with a thin film of a soft metal. The shear stress in the film will be approximately constant and will not be appreciably affected by the high pressures to which it will be subjected in the die. It should then be possible to apply a fairly rigorous theoretical treatment to the drawing process. It would be very helpful to know whether, under these conditions, the observed drawing forces can be correlated quantitatively with those predicted by theory.

Mr. G. H. Townend, B.E. (G.K.N. Research Laboratories, Ettingshall, Wolverhampton) made a number of detailed criticisms of Mr. Wistreich's paper.

Mr. D. B. Woodcock, B.Sc. (G.K.N. Research Laboratories, Lanesfield, Wolverhampton): I shall confine my remarks to the paper by Professor Christopherson and Mr. Naylor. The work has great potentialities for the wet drawing section of industry, but I feel that it has little to recommend it to dry drawers in its present form. I say this for the following reasons. First, the conversion of a dry drawing machine for use with oil tubes involves extensive modification. Secondly, much dry drawn material would not survive starting and stopping periods unless special precautions were taken. Thirdly, a good soap film on wire is extremely important when it has to be made into such articles as nails and screws. I cannot see oil lubrication performing this function. Fourthly, even if conversion of machinery and the provision of special measures necessary to overcome starting and stopping phases were thought worthwhile, for difficult-to-draw steels—for example, stainless—the high pressures required present formidable design problems, particularly if cooling of the tube becomes necessary. We must also remember that the breakdown of rod must surely be undertaken with a solid lubricant, because the tolerances of hot rolled rod preclude the small clearances implied in drawing with oils and rod also goes through tubes quite slowly. Oil tubes may well permit higher speeds, but the industry is by no means agreed that higher drawing speeds are the best way of increasing production at present. Therefore, it would be a great thing for the dry drawing part of the industry if the principles put forward by the authors were extended to the use of solid lubricants—preferably ordinary wire drawing powders. The design of tubes for use with such lubricants involves a parameter which is negligible when using oils, namely, the slip between wire and lubricant. With solids, this factor is of prime consideration, and there are few which combine properties of stability at high temperature with good powers of adhesion. Many commercially produced wire drawing powders are so dry that no pressure can be induced at speeds above the lowest normally used in industry. Moreover, when using solid lubricants the cooling of the tube is essential. Indeed, my information is that we must expect temperatures in the tube of 200 deg. or 300 deg. Cent. You will have gathered that I do not regard the use of tubes with solid lubricants in industry as quite as simple as Mr. Wistreicht suggests. It may be, however, that greatly improved performance with solid lubricants and tubes does not require pressure to exceed the yield stress of the wire. Continuity of the lubricant film—continuity of the supply of lubricant to the die mouth—may be the important thing. I doubt whether the pick-up in the soap box will ever be sufficient to maintain the higher values of q obtained by the authors, but film thicknesses achieved in the laboratory greatly exceed those achieved in normal industrial practice.

Mr. E. Freitag (Research Laboratory on the Physics and Chemistry of Surfaces, The University, Cambridge): According to Mr. Naylor's and Professor Christopherson's theory of the tube, any cross section of the wire will arrive at the die in some eccentric position. This probably does not matter, as the lubricant film converges here. But it seems unlikely that the yielding occurs symmetrically. The wire and die surfaces may not always be completely separated. I wonder whether the authors could rotate the die and pressure tube slowly in order to create journal bearing conditions which might be beneficial with respect to wear.

(*To be continued*)

Iron and Steel Institute

THE annual general meeting of the Iron and Steel Institute is to be held on Wednesday and Thursday, April 27th and 28th, at 4, Grosvenor Gardens, London, S.W.1. The first session will begin at 9.45 a.m. on April 27th, with the presentation of the council's report and statement of accounts, and the award of the Institute's medals and prizes. Following the presentations, Sir Charles Bruce-Gardner, Bt., will be inducted as president of the Institute, in succession to Hon. R. G. Lyttelton, and will deliver his presidential address.

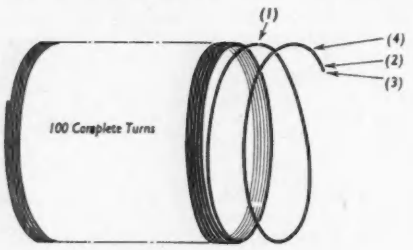
The presidential address will be followed by a discussion on a paper by Mr. C. E. Sayer, entitled "The Gas Turbo-Driven Blower for Blast-Furnace Service." A buffet luncheon will be served in the Institute's library from 1.30 p.m. to 2.30 p.m. on Wednesday, April 27th, and at the afternoon session, beginning at 2.30 p.m., there is to be a joint discussion on the two following papers: "Charging Delays due to Furnace Bunching," by Mr. R. Solt, and "The Supply of Scrap to Open-Hearth Furnaces," by Mr. M. D. J. Brisby and Mr. W. O. Pendray. The morning session on Thursday, April 28th will begin at 10.30 a.m., when the papers to be discussed are: "Causes of Variable Creep Strength in Carbon Steel," by Mr. W. E. Bardgett and Mr. M. G. Gemmill; "Creep and Rupture Data on Mo, Cr-Mo and Mo-V Steels," by Mr. J. Glen; "Statistical Study of Creep and Fatigue Properties of a Precision-Cast High-Temperature Alloy," by Mr. G. T. Harris and Mr. H. C. Child; and "Relationships between Long and Short Time Creep and Tensile Properties of a Commercial Alloy," by Mr. A. Graham and Mr. K. F. A. Walles. At the concluding session of the meeting, beginning at 2.30 p.m. on April 28th, the papers for discussion are: "Mechanism of Accelerated Attack on Metals and Alloys by V_2O_5," by Mr. G. Lucas, Mr. H. Weddle and Mr. A. Preece, and "Effect of Composition of Gas Turbine Alloys on Resistance to Scaling and to V_2O_5 Attack," by Mr. G. T. Harris, Mr. H. C. Child and Mr. J. A. Kerr

Wheatstone Bridge for Two Systems of Units

By W. H. F. GRIFFITHS, F.Inst.P., M.I.E.E., S.M.I.R.E.

Many manufacturers appear to be loath to change from the older "International" electrical units to the absolute units which were adopted in 1948. Submarine cable companies still require their test equipment to be calibrated in terms of the original B.A. units. In this article, which is concerned with resistance measurement, the author describes a Wheatstone bridge designed to measure resistance (to an accuracy of 10^{-4}) in any two of the three systems still in use.

ALTHOUGH the International agreement to adopt the Absolute system of electrical units was implemented as long ago as 1948, the author still finds that many manufacturing companies express reluctance to change completely from the older International units in which a large amount of their capital equipment is calibrated and adjusted. Important submarine cable companies, indeed, still demand that their test equipment be standardised in the original B.A. units, which were introduced in a very early attempt by the British Association to produce some uniformity of measurement. These units were the first of four systems which have been in use in this country, for the B.A. units were replaced by the Board of Trade units before the British National Physical Laboratory and the standardising laboratories of many countries adopted the so-called "International" Units in the year 1908. Then, in 1929, it will be remembered that the Advisory Committee on Electricity resolved that the Absolute system, derived from the centimetre-gramme-second system, should replace the International system of units for all measurements in science and industry. The resolution was officially approved in the same year, but, because of many delays, the date for the change to the



1—Original B.A. unit.
2—Board of Trade unit.
3—International unit (1908).
4—Absolute unit (1948).

Fig. 1—Diagram showing relative magnitude of changes in the value of the ohm, in terms of a coil with a nominal length of 100 turns

new units was fixed for January 1, 1940. After the further interruption of the war the International Committee in 1946 fixed the date for the change as January 1, 1948, and the ratios as :

1 International ohm = 1·00049 ohm absolute.

1 International volt = 1·00034 volt absolute.

The reluctance to change from International units to Absolute units finds practical expression principally in resistance measurement. The reason for this is to be found in the fact that resistance measurement, particularly d.c. resistance measurement by Wheatstone bridge, has for a long time been performed commercially with an accuracy of 10^{-4}, whereas that of capacitance and inductance had not, prior to 1948, been so accurate as to be greatly disturbed by a change of the order of 5×10^{-4}.

It is the purpose of this article, therefore, to deal principally with resistance measurement and to describe a bridge which the author has designed to measure with equal accuracy resistance in any two of the three systems of units still in use, despite International agreement, to an accuracy of 10^{-4}. Before proceeding, however, it may be interesting to give some idea as to how the magnitude of the ohm has changed since the original B.A. unit was used. The first change was tremendous—no less than 1·35 per cent—and was an increase. The second change (to the long enduring International ohm) was a further increase by 0·01 per cent only—not a very significant change for the commercial world in those days (1908). The recent change was a *reduction* by nearly 0·05 per cent. The relative magnitude of these changes is depicted in Fig. 1, the dimensions of the ohm being numbered in chronological order.

Let α be the fractional difference between the two systems of units in which resistance is required to be measured to an accuracy

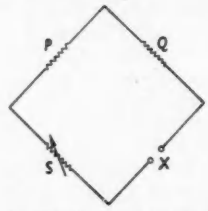


Fig. 2—Simple Wheatstone bridge

of 0·01 per cent by the simple Wheatstone bridge shown diagrammatically in Fig. 2.

Let p and q be the *nominal* values of the ratio arms P and Q, s the *nominal* value of the "known" arm S and x the *actual* value of the "unknown" X in whichever units the measurement is being made.

Using the larger of the alternative units, the resistance elements of the arms P and S are adjusted to be less than the nominal value by an amount $\frac{1}{2}\alpha$. The ratio arm Q is adjusted to be correct to nominal value in the smaller of the alternative units.

When using the bridge to measure (without correction) in the smaller of the alternative units, we have, using these units throughout

$$x=\frac{q}{p\left(1+\frac{\alpha}{2}\right)}s\left(1+\frac{\alpha}{2}\right) \quad . \quad . \quad . \quad (1)$$

$$=qs/p.$$

Since q, s and p are nominal values, no correction is necessary to give the value x in the required units.

To use the same bridge to measure (still without correction) in the larger of the units, the ratios P and Q are transposed and then, using the larger units throughout, the balance equation becomes

$$x=\frac{ps}{q}\,\frac{\left(1-\frac{\alpha}{2}\right)^2}{1-\alpha} \quad . \quad . \quad . \quad . \quad (2)$$

Expanding the numerator of the coefficient and using only the first and second terms of the expansion, the numerator of the coefficient term becomes $(1-\alpha)$, making the whole coefficient term unity and

$$x=ps/q$$

to the accuracy which is governed by the magnitude of the third term of the binomial expansion.

The bridge is arranged to have independent pairs of "X" terminals (a pair for either system of units) and these are selected by unlinking the pair to be used, the action of unlinking automatically transposing the ratio arms so as to avoid the possibility of error.

The first example in the use of this principle is the design of a Wheatstone bridge to measure resistance with equal accuracy in both International and Absolute units. In this case $\alpha=5\times10^{-4}$ and the neglected third term of the expansion of the numerator of the coefficient term of equation (2) amounts to only $+6\cdot25\times10^{-8}$ and so the error caused by this approximation in measurements in International units will be entirely negligible.

A Wheatstone bridge of this kind may also be designed which will measure accurately in both International and British Association units* of resistance. Such a bridge would be extremely useful to submarine cable organisations which still use both systems of units. In this example $\alpha=1\cdot35\times10^{-2}$ and the omitted third term of the binomial expansion becomes much larger. It is $4\cdot556\times10^{-5}$ and so the approximation is only just permissible for an accuracy of 10^{-4} when measuring in International units.

One disadvantage of this system of alternative unit measurement is that the resistance elements of one ratio arm and of the known arm are of "awkward," non-cardinal, values and are, therefore, more difficult to adjust to an accuracy of, say, two or three parts in 10^5—the least accuracy for a bridge in which the ultimate accuracy of measurement is to be always better than one part in 10^4.

In the case of a bridge to measure alternatively in the International and Absolute systems, however, the fractional difference, α, between the two sets of units is only 5×10^{-4}. The resistance elements, therefore, have to be adjusted only $2\cdot5\times10^{-4}$ off the cardinal values of the "standards" which are being used for such adjustment. Such a difference may be easily accommodated in a slide wire adjustment when using the Carey Foster method of resistance measurement, thus obviating the necessity for specially adjusted standards. The standards used may, of course, be those of either International or Absolute units.

In the case of a bridge to measure alternatively in International or B.A. unit systems, the fractional difference, α, is much greater, however, and the resistance elements must be adjusted 0·675 per cent off cardinal values. Obviously, this amount is much too large to be accommodated by a Carey Foster slide-wire difference and so it would appear to be necessary to construct a set of special "standards" against which the individual resistance coils of the bridge arms P and S could be compared and adjusted. This troublesome task may be avoided, however, by using the existing usual standards of "International" units and by shunting each one by a resistance y such that

$$\frac{Ry}{R+y}=R\left(1-\frac{\alpha}{2}\right).$$

* The actual value of the B.A. unit appears to be shrouded in mystery. Some standardising institutions deny its existence—others assign to it various values. The author uses the value 0·98651 ohm International or 0·986993 ohm Absolute as that which several large cable organisations have accepted for half a century.

Thus, the value of the shunt y to a standard of any value R is

$$y=\frac{R\left(1-\frac{\alpha}{2}\right)}{\frac{\alpha}{2}}.$$

In the particular case of the International/B.A. unit bridge the value of $\left(1-\frac{\alpha}{2}\right)\Big/\frac{\alpha}{2}$ is 147·147 and so, if each International standard is shunted by a resistance 147·15 times its own value, a new standard for the adjustment of the P and S arms is formed. Admittedly the values of these shunts are themselves awkward but this is of no consequence because, of course, the accuracy to which it is necessary to adjust them is merely 1/150 of that to which the standards themselves are known, say, $150\times2\times10^{-5}$ or 0·3 per cent only—quite a crude shunt requiring no skill to construct and no ageing or permanence comparable with that of the standard.

By adopting a Wheatstone bridge designed on this principle the cable companies could avoid the expensive and cumbersome Gott's ratio arm method of converting their B.A. unit bridges for measurements in International units.

For universal use by submarine cable organisations a Wheatstone bridge of precision must be capable of use for the localisation of cable faults by either the Varley Loop or Murray Loop tests. It must, therefore, be proved that a bridge arranged as described above may be used for these specialised measurements in either of the alternative systems of units, International and B.A.

The Murray Loop test is shown diagrammatically in Fig. 3, in which the total resistance, l, of the cable is divided into sections x and y by the fault.

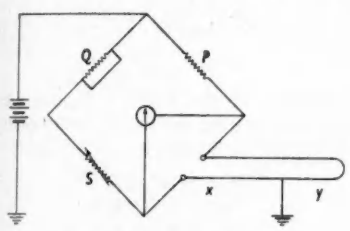


Fig. 3—Murray loop test

If $x+y=l$

$$x=\frac{S}{P+S}.l$$

and

$$y=\frac{P}{P+S}.l.$$

If the bridge is used for Murray Loop fault locating using B.A. units, it is arranged as in Fig. 3.

The values of P and S in these units are $p\left(1+\frac{\alpha}{2}\right)$ and $s\left(1+\frac{\alpha}{2}\right)$ respectively,

$$x=\frac{s\left(1+\frac{\alpha}{2}\right)}{(p+s)\left(1+\frac{\alpha}{2}\right)}.l.$$

Similarly

$$y=\frac{p\left(1+\frac{\alpha}{2}\right)}{(p+s)\left(1+\frac{\alpha}{2}\right)}.l$$

and so, since the coefficient $\left(1+\frac{\alpha}{2}\right)$ appears in both numerator and denominator, the normal equation to the fault may be used without correction.

If the same bridge is used for Murray Loop fault testing using International units of resistance the diagram of Fig. 3 is unaltered and the formulæ for the resistance x and y to the fault are unchanged. Moreover, since the resistance values of arms P and S are both changed by the same amount

$$\left(\text{from } p\left(1+\tfrac{\alpha}{2}\right) \text{ and } s\left(1+\tfrac{\alpha}{2}\right) \text{ to } p\left(1-\tfrac{\alpha}{2}\right) \text{ and } s\left(1-\tfrac{\alpha}{2}\right) \text{ respectively}\right)$$

there will be no change in the final fault formulæ, for,

$$x_{(\text{ind})}=\frac{s\left(1-\frac{\alpha}{2}\right)}{(p+s)\left(1-\frac{\alpha}{2}\right)}.l$$

$$y_{(\text{ind})}=\frac{p\left(1-\frac{\alpha}{2}\right)}{(p+s)\left(1-\frac{\alpha}{2}\right)}.l.$$

It is seen, therefore, that this novel bridge may be used for Murray Loop fault testing without complication and that the fault distances may be determined using the usual formulæ without extra computation. Fault determination by the Varley Loop method, however, is not dismissed so easily.

The Varley Loop test is shown in Fig. 4,

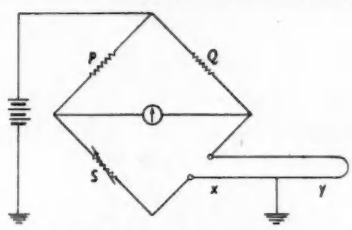


Fig. 4—Varley loop test

in which the bridge is that used for all previous examples.

If

$$l=x+y$$

$$x=\frac{lP-SQ}{P+Q}$$

$$x=\frac{lp\left(1+\frac{\alpha}{2}\right)-qs\left(1+\frac{\alpha}{2}\right)}{p\left(1+\frac{\alpha}{2}\right)+q}$$

$$=\frac{\left(1+\frac{\alpha}{2}\right)(lp-qs)}{\left(1+\frac{\alpha}{2}\right)\left\{p+q\left(1-\frac{\alpha}{2}\right)\right\}}$$

$$=\frac{lp-qs}{p+q\left(1-\frac{\alpha}{2}\right)} \quad \ldots\ldots (3)$$

Bringing p and q to nominal equality, as is done in practice,

$$x=\frac{lp-ps}{p+p\left(1-\frac{\alpha}{2}\right)}$$

$$=\frac{l-s}{2-\frac{\alpha}{2}}$$

$$=\frac{l-s}{2}\cdot\frac{1}{1-\frac{\alpha}{4}}$$

$$\doteqdot\frac{l-s}{2}+\frac{l-s}{\frac{8}{\alpha}}$$ [by an approximation producing a neglible error of $-\alpha^2/16$.]

$$\doteqdot\frac{l-s}{2}+\frac{l-s}{600} \quad \ldots\ldots (4)$$

to an accuracy of $-\frac{\alpha^2}{16}-2\left(\frac{\alpha}{8}-\frac{1}{600}\right)$ the total error caused by both approximations being -5×10^{-5}. The first term will be recognised as the usual evaluation of x and it will be seen that the correction term has been reduced, by approximation, to a very simple form.

If it is required to use the Varley Loop test when working in International units the

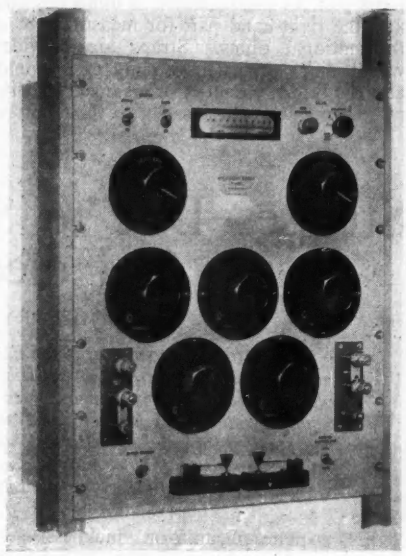


Fig. 5—Wheatstone bridge designed and built for resistance measurements in two systems of units

ratios P and Q should be transposed in order to obtain a simple formula for x.

Thus,

$$x=\frac{lQ-SP}{P+Q} \text{ where } l=x+y,$$

$$x=\frac{lq(1-\alpha)-s\left(1-\frac{\alpha}{2}\right)p\left(1-\frac{\alpha}{2}\right)}{p\left(1-\frac{\alpha}{2}\right)+q(1-\alpha)}$$

$$=\frac{\left(1-\frac{\alpha}{2}\right)^2(lq-sp)}{\left(1-\frac{\alpha}{2}\right)\left\{p+q\left(1-\frac{\alpha}{2}\right)\right\}}$$

$$=\frac{\left(1-\frac{\alpha}{2}\right)(lq-sp)}{p+q\left(1-\frac{\alpha}{2}\right)} \quad \ldots\ldots (5)$$

Bringing p and q to nominal equality, we have

$$x=\frac{p\left(1-\frac{\alpha}{2}\right)(l-s)}{p\left\{1+\left(1-\frac{\alpha}{2}\right)\right\}}$$

$$=\frac{1-\frac{\alpha}{2}}{2-\frac{\alpha}{2}}(l-s)$$

$$\doteqdot\left(1-\frac{\alpha}{4}\right)\cdot\frac{l-s}{2}$$ [by an approximation which produces a negligible error of $+\alpha^2/16$.]

$$\doteqdot\frac{l-s}{2}-\frac{l-s}{\frac{8}{\alpha}}$$

$$x\doteqdot\frac{l-s}{2}-\frac{l-s}{600} \quad \ldots\ldots (6)$$

to an accuracy just better than 5×10^{-5},

the errors being $+\frac{\alpha^2}{16}$ and $+2\left(\frac{\alpha}{8}-\frac{1}{600}\right)$ for the former and latter approximations respectively.

Again, it is seen, the necessary correction to the usual formula has been reduced to a very simple form for easy evaluation and application.

A Wheatstone bridge constructed according to the principles described in this article is illustrated in Fig. 5. It is seen that two pairs of X terminals are provided—the left-hand pair for measurement in ohms absolute and the right-hand pair for measurement in International ohms. Straps are provided which short circuit these pairs of terminals and the bridge circuit is so arranged that the ratio arms are transposed into their correct positions by the action of unlinking the pair of X terminals appropriate to the system of units in which the measurement is to be effected. In the illustration it will be seen that the bridge is arranged for measurements in ohms absolute, the action of unlinking the left-hand pair of X terminals, by linking to a third terminal, having automatically arranged the bridge circuit as in Fig. 2. Thereafter, the operation of the bridge is quite without complication—the operator, in fact, is entirely unaware of any special feature concerning the bridge or its operation.

In conclusion, the author wishes to express his indebtedness to H. W. Sullivan, Ltd., his co-patentee, for permission to publish the details of this novel bridge.

Stresses Due to Shearing Force in a Holed Plate

By HENRY G. EDMUNDS

It is sometimes necessary to bore holes in girder webs and there is an obvious need to know what stress distribution arises around such a hole. Toward the solution of this problem Tuzi analysed the stresses around a circular hole in a plate in pure bending, and Neuber† analysed the stresses due to tension, bending and shearing force around an elliptical hole. This article presents an alternative to Neuber's approach for the case of a circular hole under a shearing force, and the theoretical result is compared with a photoelastic investigation.*

LET a plate of uniform thickness c be arranged as a beam of uniform depth $2b$. At mid-depth the plate is pierced by a hole of radius a, and the object is to analyse the stresses induced around the hole by a shearing force F. It is assumed that b is large compared with a, that the bending moment on the vertical transverse section through the centre of the hole is zero, and that no loads are applied to the plate in the vicinity of the hole.

Since b is large compared with a, it follows that, at a circle of radius b drawn concentric with the hole, the stresses are sensibly unaffected by the presence of the hole. Taking the centre of the hole as the origin

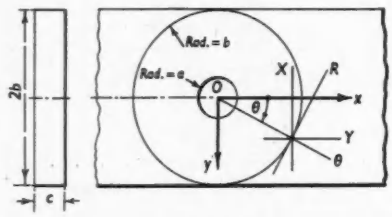


Fig. 1

of co-ordinate axes (Fig. 1), elementary theory describes the vertical shearing stress at $r=b$ as varying parabolically with y, as follows :

$$\tau'_{xy}=\frac{3}{4}\left(\frac{F}{cb}\right)\left\{1-\left(\frac{y}{b}\right)^2\right\}$$

Writing :

$$y=b\sin\theta,$$

$$\left.\begin{aligned}\tau'_{xy}&=\frac{3}{4}\left(\frac{F}{cb}\right)(1-\sin^2\theta)\\ \text{Also}\quad \sigma'_x&=\sigma'_y=0\end{aligned}\right\} \quad . \; . \; . \quad (1)$$

The state of stress described by (1) may be interpreted in terms of radial and circumferential stresses by reference to the Mohr's circle shown in Fig. 2 :

$$\left.\begin{aligned}\sigma'_r&=\tau'_{xy}\sin 2\theta\\ \text{and}\quad \tau'_{r\theta}&=\tau'_{xy}\cos 2\theta\end{aligned}\right\}$$

Substituting the value of τ'_{xy} from (1), and modifying suitably leads to :

$$\left.\begin{aligned}\sigma'_r&=\frac{3}{16}\left(\frac{F}{cb}\right)(\sin 4\theta+2\sin 2\theta)\\ \text{and}\quad \tau'_{r\theta}&=\frac{3}{16}\left(\frac{F}{cb}\right)(\cos 4\theta+2\cos 2\theta+1)\end{aligned}\right\} \quad . \quad (2)$$

Thus, the shearing force in the vicinity of

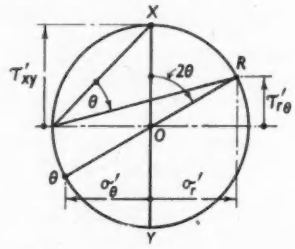


Fig. 2

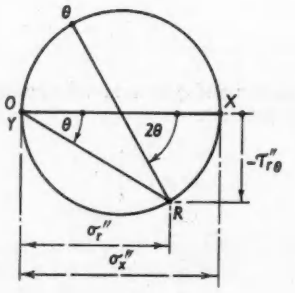


Fig. 3

the hole being F, the stresses at $r=b$ due to F alone are as described in (2). Clearly, however, the boundary of the hole being unloaded, (2) does not describe an equilibrium state and on the annulus between $r=a$ and $r=b$ there acts a net torque of $\left(\frac{3\pi}{8}\right)F\,.\,b$.

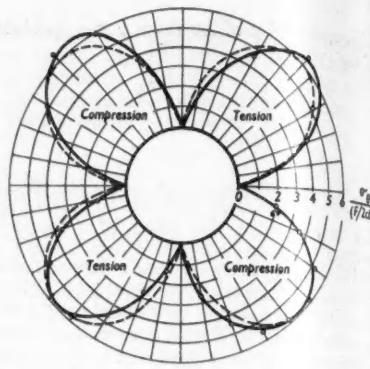


Fig. 4

This arises because the shearing force cannot exist unless the bending moment diagram has a gradient, and although the bending moment at $x=0$ is zero, nevertheless, on the circle of radius b there are bending stresses of which account must be taken.

In general :

$$F=dM/dx,$$

but since the plate bears no loads within the region considered, F is constant and :

$$M=F\,.\,x\,.$$

On the circle of radius b :

$$x=b\cos\theta,$$

whence

$$M=F\,.\,b\,.\cos\theta\,.$$

The corresponding stress σ''_x is given by :

$$\sigma''_x=(M/I)\,y\,.$$

Substituting for M and y :

At $r=b$:

$$\left.\begin{aligned}\sigma''_x&=\left(\frac{Fb^2}{2I}\right)\sin 2\theta\\ \text{and}\quad \sigma''_y&=\tau''_{xy}=0\end{aligned}\right\} \quad . \; . \quad (3)$$

By reference to the Mohr's circle shown in Fig. 3, (3) may be written in terms of radial and tangential stresses :

$$\sigma''_r=\tfrac{1}{2}\sigma''_x(1+\cos 2\theta)$$
$$\tau''_{r\theta}=-\tfrac{1}{2}\sigma''_x\sin 2\theta.$$

Substituting the value of σ''_x from (3) :

$$\left.\begin{aligned}\sigma''_r&=\frac{3}{16}\left(\frac{F}{cb}\right)(\sin 4\theta+2\sin 2\theta)\\ \tau''_{r\theta}&=\frac{3}{16}\left(\frac{F}{cb}\right)(\cos 4\theta-1)\end{aligned}\right\} \quad . \quad (4)$$

The total effect of the shearing force and the associated gradient of bending moment may be determined by adding (2) and (4) :

$$\left.\begin{aligned}\sigma_r=\sigma'_r+\sigma''_r&=\frac{3}{8}\left(\frac{F}{cb}\right)(\sin 4\theta+2\sin 2\theta)\\ \tau_{r\theta}=\tau'_{r\theta}+\tau''_{r\theta}&=\frac{3}{8}\left(\frac{F}{cb}\right)(\cos 4\theta+\cos 2\theta)\end{aligned}\right\} \quad . \quad (5)$$

Thus the original problem has been converted to one of determining the stress distribution in an annulus on which the following boundary conditions are fulfilled :

At $r=a$	At $r=b$
$\sigma_r=0$	$\sigma_r=-\frac{3}{8}\left(\frac{F}{cb}\right)(\sin 4\theta+2\sin 2\theta)$
$\tau_{r\theta}=0$	$\tau_{r\theta}=-\frac{3}{8}\left(\frac{F}{cb}\right)(\cos 4\theta+\cos 2\theta)$

It is convenient to take the components of boundary stresses in separate pairs and then superimpose the results. Take first :

At $r=a$	At $r=b$
$\sigma_r=0$	$\sigma_r=-\frac{3}{8}\left(\frac{F}{cb}\right)\sin 4\theta$
$\tau_{r\theta}=0$	$\tau_{r\theta}=-\frac{3}{8}\left(\frac{F}{cb}\right)\cos 4\theta$

* Tuzi, Z. *Phil. Mag.*, February, 1930, page 210.
† Neuber, H. "Kerbspannungslehre."

The appropriate stress function $\phi_1(r,\theta)$ must satisfy the equation :

$$\left(\frac{\partial^2}{\partial r^2}+\frac{1}{r}\frac{\partial}{\partial r}+\frac{1}{r^2}\frac{\partial^2}{\partial\theta^2}\right)\left(\frac{\partial^2\phi_1}{\partial r^2}+\frac{1}{r}\frac{\partial\phi_1}{\partial r}+\frac{1}{r^2}\frac{\partial^2\phi_1}{\partial\theta^2}\right)=0.$$

Assuming ϕ_1 to be of the form :

$$\phi_1=Kr^m\sin 4\theta,$$

it may be shown by substitution that m may have the values 6, 4, −2 and −4, i.e. :

$$\phi_1=(Ar^6+Br^4+Cr^{-2}+Dr^{-4})\sin 4\theta.$$

Now :

$$\sigma_{r1}=\frac{1}{r}\left(\frac{\partial\phi_1}{\partial r}\right)+\frac{1}{r^2}\left(\frac{\partial^2\phi_1}{\partial\theta^2}\right)$$

and $$\sigma_{\theta1}=\frac{\partial^2\phi_1}{\partial r^2}$$

and $$\tau_{r\theta1}=-\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial\phi_1}{\partial\theta}\right)$$

i.e.

$$\left.\begin{aligned}\sigma_{r1}&=-(10Ar^4+12Br^2+18Cr^{-4}\\&\qquad+20Dr^{-6})\sin 4\theta\\ \text{and}\quad\tau_{r\theta1}&=-(20Ar^4+12Br^2-12Cr^{-4}\\&\qquad-20Dr^{-6})\cos 4\theta\end{aligned}\right\}\quad .\quad(6)$$

Substituting the known boundary conditions in (6) :

$$\left.\begin{aligned}10a^{10}.A+12a^8.B+18a^2.C+20D&=0\\ 20a^{10}.A+12a^6.B-12a^2.C-20D&=0\\ 10b^{10}.A+12b^8.B+18b^2.C+20D&\\=-\frac{3}{8}\left(\frac{F}{cb}\right)b^6&\\ 20b^{10}.A+12b^8.B-12b^2.C-20D&\\=-\frac{3}{8}\left(\frac{F}{cb}\right)b^6&\end{aligned}\right\}\quad .\quad(7)$$

The solution of (7) yields the following values of A, B, C and D :

$$A=\frac{\frac{3}{8}\left(\frac{F}{cb}\right)\left(\frac{a}{b}\right)^{10}\left(\frac{1}{a}\right)^4\left\{1-\left(\frac{a}{b}\right)^2\right\}}{\left\{1-16\left(\frac{a}{b}\right)^6+30\left(\frac{a}{b}\right)^8-16\left(\frac{a}{b}\right)^{10}+\left(\frac{a}{b}\right)^{16}\right\}}$$

$$\doteqdot\frac{3}{8}\left(\frac{F}{cb}\right)\left(\frac{a}{b}\right)^{10}\left(\frac{1}{a}\right)^4.$$

$$B=\frac{-\frac{1}{32}\left(\frac{F}{cb}\right)\left(\frac{a}{b}\right)^2\left(\frac{1}{a}\right)^2\left\{1+15\left(\frac{a}{b}\right)^8-16\left(\frac{a}{b}\right)^{10}\right\}}{\left\{1-16\left(\frac{a}{b}\right)^6+30\left(\frac{a}{b}\right)^8-16\left(\frac{a}{b}\right)^{10}+\left(\frac{a}{b}\right)^{16}\right\}}$$

$$\doteqdot-\frac{1}{32}\left(\frac{F}{cb}\right)\left(\frac{a}{b}\right)^2\left(\frac{1}{a}\right)^2.$$

$$C=\frac{\frac{1}{8}\left(\frac{F}{cb}\right)\left(\frac{a}{b}\right)^2a^4\left\{1-\left(\frac{a}{b}\right)^{10}\right\}}{\left\{1-16\left(\frac{a}{b}\right)^6+30\left(\frac{a}{b}\right)^8-16\left(\frac{a}{b}\right)^{10}+\left(\frac{a}{b}\right)^{16}\right\}}$$

$$\doteqdot\frac{1}{8}\left(\frac{F}{cb}\right)\left(\frac{a}{b}\right)^2a^4.$$

$$D=\frac{-\frac{3}{32}\left(\frac{F}{cb}\right)\left(\frac{a}{b}\right)^2a^6\left\{1-\left(\frac{a}{b}\right)^8\right\}}{\left\{1-16\left(\frac{a}{b}\right)^6+30\left(\frac{a}{b}\right)^8-16\left(\frac{a}{b}\right)^{10}+\left(\frac{a}{b}\right)^{16}\right\}}$$

$$\doteqdot-\frac{3}{32}\left(\frac{F}{cb}\right)\left(\frac{a}{b}\right)^2a^6.$$

Using the approximate values of these constants :

$$\phi_1=\frac{1}{32}\left(\frac{F}{cb}\right)\left(\frac{a}{b}\right)^2\left\{12\left(\frac{a}{b}\right)^8\cdot\frac{r^6}{a^4}-\frac{r^4}{a^2}+4\cdot\frac{a^4}{r^2}-3\frac{a^6}{r^4}\right\}\sin 4\theta.$$

From this function the stresses are deduced as follows :

$$\left.\begin{aligned}\sigma_{r1}&=-\frac{3}{8}\left(\frac{F}{cb}\right)\left(\frac{a}{b}\right)^2\left\{10\left(\frac{a}{b}\right)^8\left(\frac{r}{a}\right)^4-\left(\frac{r}{a}\right)^2\right.\\&\qquad\left.+6\left(\frac{a}{r}\right)^4-5\left(\frac{a}{r}\right)^6\right\}\sin 4\theta\\ \sigma_{\theta1}&=\frac{3}{8}\left(\frac{F}{cb}\right)\left(\frac{a}{b}\right)^2\left\{30\left(\frac{a}{b}\right)^8\left(\frac{r}{a}\right)^4-\left(\frac{r}{a}\right)^2\right.\\&\qquad\left.+2\left(\frac{a}{r}\right)^4-5\left(\frac{a}{r}\right)^6\right\}\sin 4\theta\\ \tau_{r\theta1}&=-\frac{3}{8}\left(\frac{F}{cb}\right)\left(\frac{a}{b}\right)^2\left\{20\left(\frac{a}{b}\right)^8\left(\frac{r}{a}\right)^4-\left(\frac{r}{a}\right)^2\right.\\&\qquad\left.-4\left(\frac{a}{r}\right)^4+4\left(\frac{a}{r}\right)^6\right\}\cos 4\theta\end{aligned}\right\}\quad .\quad(8)$$

For the second part of the solution the boundary conditions are :

At $r=a$	At $r=b$
$\sigma_r=0$	$\sigma_r=-\frac{3}{4}\left(\frac{F}{cb}\right)\sin 2\theta$
$\tau_{r\theta}=0$	$\tau_{r\theta}=-\frac{3}{8}\left(\frac{F}{cb}\right)\cos 2\theta$

The stress function ϕ_2 is found to be :

$$\phi_2=(Er^4+Gr^2+H+Jr^{-2})\sin 2\theta,$$

and the values of the constants as determined from the boundary conditions are :

$$E=\frac{\frac{1}{16}\left(\frac{F}{cb}\right)\left(\frac{a}{b}\right)^2\left(\frac{1}{a}\right)^2\left\{1+8\left(\frac{a}{b}\right)^2-9\left(\frac{a}{b}\right)^4\right\}}{\left\{1-4\left(\frac{a}{b}\right)^2+6\left(\frac{a}{b}\right)^4-4\left(\frac{a}{b}\right)^6+\left(\frac{a}{b}\right)^8\right\}}$$

$$\doteqdot\frac{1}{16}\left(\frac{F}{cb}\right)\left(\frac{a}{b}\right)^2\left(\frac{1}{a}\right)^2.$$

$$G=\frac{-\frac{3}{8}\left(\frac{F}{cb}\right)\left\{1+2\left(\frac{a}{b}\right)^4-3\left(\frac{a}{b}\right)^6\right\}}{\left\{1-4\left(\frac{a}{b}\right)^2+6\left(\frac{a}{b}\right)^4-4\left(\frac{a}{b}\right)^6+\left(\frac{a}{b}\right)^8\right\}}$$

$$\doteqdot-\frac{3}{8}\left(\frac{F}{cb}\right).$$

$$H=\frac{\frac{3}{4}\left(\frac{F}{cb}\right)a^2\left\{1-\frac{1}{4}\left(\frac{a}{b}\right)^2-\frac{3}{4}\left(\frac{a}{b}\right)^6\right\}}{\left\{1-4\left(\frac{a}{b}\right)^2+6\left(\frac{a}{b}\right)^4-4\left(\frac{a}{b}\right)^6+\left(\frac{a}{b}\right)^8\right\}}$$

$$\doteqdot\frac{3}{4}\left(\frac{F}{cb}\right)a^2.$$

$$J=\frac{-\frac{3}{8}\left(\frac{F}{cb}\right)a^4\left\{1-\frac{1}{3}\left(\frac{a}{b}\right)^2-\frac{2}{3}\left(\frac{a}{b}\right)^4\right\}}{\left\{1-4\left(\frac{a}{b}\right)^2+6\left(\frac{a}{b}\right)^4-4\left(\frac{a}{b}\right)^6+\left(\frac{a}{b}\right)^8\right\}}$$

$$\doteqdot-\frac{3}{8}\left(\frac{F}{cb}\right)a^4.$$

Again using the approximate values of these constants :

$$\phi_2=\frac{1}{16}\left(\frac{F}{cb}\right)\left\{\left(\frac{a}{b}\right)^2\cdot\left(\frac{r^4}{a^4}\right)-6r^2+12a^2-6\left(\frac{a^4}{r^2}\right)\right\}\sin 2\theta.$$

The stresses derived from this function are :

$$\left.\begin{aligned}\sigma_{r2}&=\frac{3}{4}\left(\frac{F}{cb}\right)\left\{1-4\left(\frac{a}{r}\right)^2+3\left(\frac{a}{r}\right)^4\right\}\sin 2\theta.\\ \sigma_{\theta2}&=\frac{3}{4}\left(\frac{F}{cb}\right)\left\{\left(\frac{a}{b}\right)^2\left(\frac{r}{a}\right)^2-1-3\left(\frac{a}{r}\right)^4\right\}\sin 2\theta.\\ \tau_{r\theta2}&=-\frac{3}{8}\left(\frac{F}{cb}\right)\left\{\left(\frac{a}{b}\right)^2\left(\frac{r}{a}\right)^2-2-4\left(\frac{a}{r}\right)^2\right.\\&\qquad\left.+6\left(\frac{a}{r}\right)^4\right\}\cos 2\theta.\end{aligned}\right\}\quad .\ .\ .\ (9)$$

The total stresses in the plate are determined by adding (8) and (9) :

$$\sigma_r=\sigma_{r1}+\sigma_{r2}$$

$$\sigma_\theta=\sigma_{\theta1}+\sigma_{\theta2}$$

$$\tau_{r\theta}=\tau_{r\theta1}+\tau_{r\theta2}$$

$$\sigma_r=\frac{3}{8}\left(\frac{F}{cb}\right)\left[2\left\{1-4\left(\frac{a}{r}\right)^2+3\left(\frac{a}{r}\right)^4\right\}\sin 2\theta-\left(\frac{a}{b}\right)^2\left\{10\left(\frac{a}{b}\right)^8\left(\frac{r}{a}\right)^4-\left(\frac{r}{a}\right)^2+6\left(\frac{a}{r}\right)^4-5\left(\frac{a}{r}\right)^6\right\}\sin 4\theta\right].$$

$$\sigma_\theta=\frac{3}{8}\left(\frac{F}{cb}\right)\left[2\left\{\left(\frac{a}{b}\right)^2\left(\frac{r}{a}\right)^2-1-3\left(\frac{a}{r}\right)^4\right\}\sin 2\theta+\left(\frac{a}{b}\right)^2\left\{30\left(\frac{a}{b}\right)^8\left(\frac{r}{a}\right)^4-\left(\frac{r}{a}\right)^2+2\left(\frac{a}{r}\right)^4-5\left(\frac{a}{r}\right)^6\right\}\sin 4\theta\right].$$

$$\tau_{r\theta}=-\frac{3}{8}\left(\frac{F}{cb}\right)\left[\left\{\left(\frac{a}{b}\right)^2\left(\frac{r}{a}\right)^2-2-4\left(\frac{a}{r}\right)^2+6\left(\frac{a}{r}\right)^4\right\}\cos 2\theta-\left(\frac{a}{b}\right)^2\left\{20\left(\frac{a}{b}\right)^8\left(\frac{r}{a}\right)^4-\left(\frac{r}{a}\right)^2-4\left(\frac{a}{r}\right)^4+4\left(\frac{a}{r}\right)^6\right\}\cos 4\theta\right].$$

At the hole where $r=a$:

$$\sigma_\theta=-3\cdot\left(\frac{F}{cb}\right)\left[\left\{1-\frac{1}{4}\left(\frac{a}{b}\right)^2\right\}\sin 2\theta+\left\{\frac{1}{2}\left(\frac{a}{b}\right)^2-\frac{15}{4}\left(\frac{a}{b}\right)^{10}\right\}\sin 4\theta\right].$$

and for a small hole :

$$\sigma_\theta=-3\left(\frac{F}{cb}\right)\sin 2\theta.$$

In Fig. 4 this result is compared with the results of an experiment on a photoelastic model. Unsymmetrical four-point loading was used, and the hole was placed where the bending moment was calculated to be zero. The ratio $\left(\frac{a}{b}\right)$ was 0·295. The boundary stresses at a number of positions around the hole were estimated with a Babinet compensator, and the results are indicated in Fig. 4 by the small circles. Through these points full line curves have been drawn, whilst the interrupted lines indicate the approximate theoretical result,

$$\sigma_\theta\doteqdot-3\left(\frac{F}{cb}\right)\sin 2\theta.$$

Regarding this approximation, it may be seen that this is the same result as for a small hole in a plate subjected to pure shear of magnitude $\frac{3}{4}\left(\frac{F}{cb}\right)$, and this latter is the value of the vertical shear stress at the neutral axis in the unholed plate.

The maximum stress at the hole is four times the vertical shear stress at the neutral axis or six times the average shear stress on a complete vertical section.

Technical Report

Third Report of the Ingot Moulds Sub-Committee. Special Report No. 52 of the Iron and Steel Institute. London : Iron and Steel Institute, 4, Grosvenor Gardens, S.W.1. Price 25s.—This report brings up to date the work of the Ingot Moulds Sub-Committee on ingot-mould performance and discusses the results of the practical application of recommendations made in the earlier reports. The first part considers the relationship of mould performance to the conditions of service encountered in the steel works. It states that in general any features of works practice which tend to heat up the mould more rapidly, to produce a higher temperature in the mould, or to maintain it at a high temperature for a longer period are detrimental to mould life. The chemical composition of mould iron is discussed in the second part of the report and the effects of silicon, phosphorus, manganese, sulphur and carbon are considered. Mould iron properties and conditions are dealt with in part three, and it is stated that little success has been achieved in relating these factors to mould performance, partly because the properties of test sample and mould may differ considerably. The factors of mould design are then considered and mould-weight/ingot-weight ratio, relative thickness of different parts of the mould, changes in section, &c., are discussed.

Terminal Buildings at London Airport

(*Concluded from page* 483, *April* 8*th*)

NO. III—BEAM APPROACH AND VISUAL LANDING AIDS

Certain air terminal buildings at London Airport are being commissioned this month ; they include the control tower in which is based an unusually comprehensive system of surveillance and navigational aids. Here we give a brief description of the I.L.S. equipment and the airport lighting facilities.

MENTION was made on page 461 *ante* of an airborne beam approach equipment which could be used also in association with G.C.A. surveillance. It is known as the Instrument Landing System (I.L.S.) and is made by Pye, Ltd. Immediately after the war, Pye, Ltd., embarked on a project to design and manufacture an instrument landing system. The frequencies allocated for this purpose were in the region of 110 Mc/s and 330 Mc/s. At this time, although v.h.f. frequencies in the 110 Mc/s region were in use, very little work had been done in the 330 Mc/s u.h.f. band and this involved entirely new design techniques and the use of new types of valves virtually untried operationally.

Eventually a system was produced which provided entirely satisfactory signals in the aircraft enabling the pilot to follow the localiser beam (which provides a path down the centre line of the runway) and the glide path beam (which provides a glide angle intersecting the beginning of the runway). The information is presented to the pilot by a cross pointer meter. A vertical needle indicates whether he is on the runway heading and a horizontal needle indicates his relative altitude with respect to the glide path. The particular system developed employed electronic modulation as opposed to the mechanical modulator employed in the war-time American-built instrument landing systems. This represented a considerable advance on previous systems, but equipment development in the use of 330 Mc/s frequencies had outstripped valve development, and difficulties arose owing to short valve life.

A new valve of greatly increased power to those previously employed and suitable for frequencies up to 600 Mc/s was produced and consequently it was decided to redesign the equipment. This completely new system is now being supplied to the Royal Air Force in quantity.

The operation of the system is quite simple. A localiser transmitter provides directional guidance to the airport runway ; the transmitter radiates in the band 108–112 Mc/s. Separate stages of the transmitter are modulated by 90 cycle and 150 cycle tones locked to a master tone source to ensure perfect synchronisation. Each stage has an output of 25–30W r.f. power and this output is fed to two dipole aerials positioned within a parabolic reflector. Dual transmitters are provided, with automatic changeover to standby in the event of failure occurring in the main transmitter. The relative phase and amplitudes of the signals fed to the two dipole aerials are adjusted to obtain the correct radiation pattern and in addition a 1000 cycle tone is also radiated coded to the station call sign. This arrangement enables an aircraft using the system to identify without ambiguity the airfield it is approaching. The identification signal can be replaced with an R/T channel when required from the control console. Use of a parabolic reflector is a new development, eliminating the back course of the older system. It also increases the range along the " on course " line and greatly reduces the possibility of false courses due to spurious reflections.

The glide path transmitter operates in the band 328·6–335 Mc/s and provides a glide angle which can be set between 2 deg. and 4 deg. to the horizontal. This glide angle intersects the ground at the beginning of the runway.

The operation of the glide path transmitter is somewhat similar to that of the localiser in that two output units are used, one of which is modulated by a 90 cycle and the other by 150 cycle tone, as before. The power output from each unit is approximately 12W-15W. The aerial system comprises two radiating aerials attached at different heights to a vertical mast. The lower of the two aerials is fed with the 90 cycle modulated output and the upper aerial with the 150 cycle modulated output. The heights of these aerials determines the glide angle.

For both the glide path and localiser beams, monitor aerials are placed within the radiation pattern and employed to ensure that the " on-course " signals remain within the limits specified by I.C.A.O.

Marker beacon transmitters, by which the pilot can check height and distance from the touch-down point, are used along the approach paths to the airfield runway. These operate on a frequency of 75 Mc/s and normally the outer marker is some distance from the airfield, often as much as 10 miles. The middle marker is about 3 miles out and the boundary marker is near to the beginning of the runway.

The entire ground equipment is controlled and monitored from a console normally housed in the equipment room of the flying control building; an extension unit can be provided for installation in the control room. The localiser, glide path and marker beacon transmitters are connected to the remote console by telephone lines, and in the event of an automatic changeover taking place at glide path or localiser transmitters, this is indicated at the console which shows which transmitter is in operation. A failure is indicated by an alarm lamp and bell. A further useful facility is the radio-telephone channel available on the localiser transmission, this enables speech communication with aircraft using the system.

London Airport Lighting

All the aerodrome lighting needed to enable a pilot to make a visual approach to the airport, descend to the runway, land and taxi to the unloading area, is, with certain minor exceptions, controlled from switches in the aerodrome control room. The aerodrome controller directs the following services : aerodrome location and identification beacons ; approach lighting ; runway and threshold lighting ; taxiway lighting.

Approach Lighting.—The approaches to either end of the two east-west runways are equipped with centre-line and crossbar approach lighting, a pattern which was devised by Mr. E. S. Calvert of the R.A.E. at Farnborough, and developed by the Ministry of Transport and Civil Aviation. In its present form the Calvert lighting system has been adopted as a standard by the International Civil Aviation Organisation. The Calvert system consists of a straight line of lights 3000ft long leading up to the runway and crossbar lights at right angles to this line every 500ft. The first 1000ft is formed of triple lights, the next 1000ft of double lights, and the last 1000ft, nearest the runway, of single lights. The arrangement provides a pilot with an additional guide to his distance from touch-down. In the worst weather conditions the lights shine directly in line with the beam of the radio aid at a peak brilliancy of 80,000 candle power. As visibility improves the brilliancy is reduced and when at night it is possible to see for half a mile red omni-directional lights of lower candlepower but the same pattern are switched on. They enable a pilot to line up with the runway visually from positions wide of the runway's extended centre line.

The latest variant of the system is the installation at the western end of the northerly east-west runway, which serves aircraft landing to the east. It was completed last year, and although the pattern remains practically unchanged, the light fittings are new. They are extremely light in weight and can be mounted on very slender supports, thus providing minimum obstacle to any aircraft accidentally under-shooting or running-off the end of the runway.

Runway Lighting.—The runway lights consist of white lights in two rows 150ft apart, inset from the edges and let into the concrete so that they project only 1in or 2in and can safely be run over by aircraft wheels. Each threshold of the runway is defined by a line of green lights, and for 2000ft before the far end the runway lights are fitted with yellow filters to mark a " caution zone." The intensity of the runway lighting is varied according to the weather conditions or on request.

Taxiway Lights.—The pattern of taxiways is complex and to provide a clear indication of the correct path something more than the conventional blue lights along the edge of the taxiway was required. The new system consists of a single line of flush green lights not more than 80ft apart running along the centre of the taxiway by which the captain may proceed without recourse to route diagrams and without the use of R/T. In no instance is the green line less than 50ft from the edge of the concrete and thus, without actually seeing the boundary of the taxiway, a pilot straddling the line with his main wheels is assured of a more than adequate width of hard surface. London Airport is so far the only civil airport in the world to adopt the green centre-line system which is recognised by the International Civil Aviation Organisation. There are about 1500 of these omni-directional taxiway lighting installations which are made by General Electric Company, Ltd., and have " Osram " 6V 36W lamps.

To maintain separation at points where the route crosses other taxiways, routes, or duty runways, the aerodrome is divided into sections or blocks. There are about 100 of these blocks, which vary in size but are so designed that an aircraft standing at the boundary of one is clear of traffic in adjacent blocks. Approximately half the blocks consist of junctions with other taxi tracks and the remainder are straight sections between junctions. The entrances to each block are marked by lines of red flush lights called " stop-bars " and an aircraft may not cross them when they are illuminated. When the green taxiway lights are lit on a through route all the stop-bars across that route are automatically extinguished. As all the stop-bars at other entrances to the blocks on the selected route remain at red, the aircraft is safeguarded against other traffic. Since only one route through a junction can be selected at one time, another aircraft on a conflicting route is held at a stop-bar until the first aircraft has passed and a new route has been set up for it through the junction block. A special safeguard is provided where a route crosses a runway in use by the controller supervising flying operations being compelled to operate a master switch before the green lights on a route crossing the runway in use can come up.

Even by day an indication of the route in use is needed and, as the green taxiway and red stop-bar lights are not visible on bright days, a series of diagrammatic signboards has been provided for use in these conditions. The route in use is shown by a powerful white light on the appropriate arm of the diagram.

Besides each stop-bar is a board on which are shown the numbers of the block the aircraft is in and that of the block ahead. These boards can be used either to designate check points by the control officer or to enable a pilot to check his position.

The lighting control system was provided by Standard Telephones and Cables, Ltd.

Description of Switchgear Layout.—The switches are in the arc of a circle around the north and east sides of the aerodrome control room. They are in two groups on either side of a diagram of the airport which shows by means of miniature lamps under glass which services have been selected. This diagram is known as the " Mimic." On the right of the mimic is the bank of switches controlling the runway lights, approach lights and several miscellaneous services such as obstruction lights, identification and location beacons, meteorological visibility lights and runway snow lights. To the left of the controller is the main bank of switches governing the taxiway lights and on the extreme left are switches which operate the circuits for all services.

Public Address.—A public address installation

is provided as necessary in all three buildings and this may be divided into three basic circuits.

General circuit : to provide traffic announcements to passengers and their friends by a representative of the airline or Ministry of Transport and Civil Aviation. Microphones are located in the Ministry of Transport and Civil Aviation enquiry bureau and British European Airways final control desk in the south-east face building.

Spectators' circuit : to make announcements about or running commentaries on aircraft movements or other events of interest on the airport. Also to relay recorded music to visitors in the public enclosure. The microphone is located in the commentator's room on the roof of the south-east face building.

Ministry of Transport and Civil Aviation circuit : to broadcast announcements of an urgent or special nature to passengers, spectators, and members of the airport staff. This circuit has over-riding priority over the whole of the installation if required.

An interesting feature of this installation is the use of " line source " type loudspeakers in the main concourse, roof gardens, &c., where the large areas to be covered present appreciable acoustic problems.

Control of Airfield Lighting and Navigational Services.—Although these services are in principle similar to those of many other large airports the scale and complexity of runways and taxiways necessary at London Airport to deal with the great volume of traffic has led to a control system which is in many ways unique. By their very nature the services are spread out over the greater part of the airfield and environs and the electrical load involved has necessitated the provision of some twenty substations, many of which deal with connected loads as high as 100kVA. Since most of the services comprising this load are subject to remote control, controlled or " B " centres are provided at or near the substations and are linked with the control tower by multi-core telephone type cables, which enable some 1000 control operations to be carried out from this central point.

The nerve centre for this control network is the control room situated on the ninth floor of the tower where two control desks are provided, one for airfield lighting proper and the other for the control of the taxiway lighting. Each desk operates over a separate control network. The lighting control operation carried out by these two desks is displayed on a miniaturised mimic of the airfield situated in the same room.

A great number of switching operations is involved in controlling the taxiway lighting at intersections. The taxiway lighting or ground movement control desk is of particular interest in that it has been designed to enable the large number of switching operations to be carried out with relative simplicity and speed. Each traffic junction on the airfield is allotted a pair of junction panels, one designated " in " and the other " out." These panels each contain a selector switch with a number of ways corresponding with the number of branches of the junctions with which it is associated. Routes through junctions may thus be selected quickly by placing the " in " and " out " switches in the required position. Various other keys are also provided on the desk to control remotely group power supplies to the taxi lighting, operation of the system, &c.

The airfield lighting control desk follows a more familiar pattern, comprising on/off controls for the various services, brilliancy control of several types and runway selection. This desk also carries the controls for identification and navigation beacons and obstruction lights.

These two control systems are largely separate, though certain interconnections are arranged for over-riding control of routes across selected runways so as to avoid undue delays to ground traffic arising from landing and take-off operations.

The control systems operate on a code principle so as to avoid the cost of cables containing an unwieldy number of cores. Signalling may thus be carried out basically over a few cores within the capacity of a fourteen-pair telephone cable. The signalling codes are initiated by apparatus on the first floor of the tower to which the control desk and mimics are connected by multi-core cables. Apparatus at each controlled or " B " centre interprets the signals received from the tower and translates them into the required switching functions. The whole system is battery-operated to guard against mains failure.

Designs for all the above services have been prepared by Air Ministry Directorate General of Works who have also developed the electrical control system used throughout the airport.

Roadway Lights.—The lighting of roadways leading to the central area and of spaces such as car parks within the area itself presented a number of peculiar problems. The volume of aerial traffic during the hours of darkness and the number and variety of airfield lights made it imperative to avoid confusing pilots' views of runways and taxiways. This applies particularly in conditions of poor visibility, remembering that the pilot will be looking out of his aircraft from a height of 12ft to 15ft.

The method of roadway lighting finally adopted was by G.E.C. " Three-Eighty " cut-off lanterns mounted on 30ft high steel poles. Each lantern contains three 5ft, 80W fluorescent tubes, and the optical system is so designed that no light is emitted above the horizontal. This provides good visibility in the roadways without glare either to motorists or pilots.

Apron Flood Lighting.—The apron in front of the S.E. face passenger handling building and eastern apex building will be lit at night by about fifty G.E.C. flood lights designed to comply with an Air Ministry specification. The lights are mounted on 60ft high steel towers of special design, with an average of seven lights to each tower. Illumination is provided by a 1000W " Osram " projector lamp. The main feature of these flood lights is the lightweight design—each light weighs less than 25 lb—which, coupled with the comparatively small size, enables the stresses on the tower and on the lights themselves to be kept to a minimum.

Overland Link in Transatlantic Telephone Cable

Descriptions have been published of the transatlantic telephone cable system which will provide thirty-six telephone circuits between Great Britain and the North American Continent. A general account of the whole system was given in an I.E.E. paper[1] and a short description of the manufacture of the submarine portion of the cable was given in another article.[2] Below we give some information received from the manufacturer of the overland portion of the cable, between Clarenville and Terrenceville.

AS mentioned in an earlier article[3] the project to establish a multi-channel transatlantic submarine telephone system to link the existing telephone networks of Great Britain, Canada and the U.S.A. is the result of an agreement made in November, 1953, between the American Telephone and Telegraph Company, the British Post Office and the Canadian Overseas Telecommunication Corporation. Briefly, to provide the thirty-six circuits across the Atlantic two submarine cables, each 1950 nautical miles long and having fifty-two submerged repeaters at intervals of about 37 nautical miles, will be laid between Oban in Scotland and Clarenville in Newfoundland. The repeaters in these cables are designed for one-way direction of speech transmission so that one cable furnishes the " go " channels and the other the " return " channels.

From Clarenville a land cable will cross Newfoundland to Terrenceville. This cable will contain two two-way repeaters providing for communication in both directions. From Terrenceville on the south coast of Newfoundland another submarine cable will be laid to Sydney Mines in Nova Scotia. This cable will have sixteen submerged repeaters spaced at approximately 20 nautical miles intervals and they will also amplify signals in both directions. From Sydney Mines the telephone circuits will be routed over microwave relay links and land cables to New York and Montreal, where they will connect with the U.S.A. and Canadian telephone systems.

The Overland Cable

In May, 1954, the British Post Office placed an order with W. T. Henley's Telegraph Works Company, Ltd., to supply 45 nautical miles of cable for the Clarenville-Terrenceville route and later in the year the company received another order for 9 nautical miles of similar cable in two lengths, but more heavily armoured. The cable has now been manufactured in conjunction with the associated company, Southern United Telephone Cables, Ltd. The cable for the first order was shipped aboard the S.S. " Teeswood " on April 4th at Dagenham Dock, Essex, the

Fig. 1—Pipe Hole River. The main length (about 10,000 yards) of the heavily armoured telephone cable will be laid by barge and tug along the river bed

shipment consisting of ninety-three drums. The drums will be unloaded at St. John's, Newfoundland, and taken to site by tractor-hauled trailers. The two heavily armoured lengths of 5·7 and 3·3 nautical miles will be shipped directly aboard H.M.T.S. " Monarch " at Dagenham Dock, and will be laid across the south-west arm to Queen's Cove and at Pipers Hole River as referred to later. The complete cable from Clarenville to Terrenceville is to be laid this summer.

The route between these two places consists of parts where the cable will be laid approximately

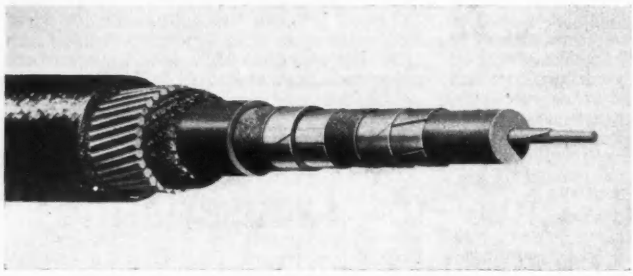


Fig. 2—Telescoped sample of the " normal " land line telephone cable to be laid between Clarenville and Terrenceville

30in deep in a trench and other parts where the cable will be laid in rivers and inlets along the route to reduce the excavation work.; where the cable is laid in this way it is more heavily armoured. Generally, the terrain through which the land cable is to be laid varies from hard rock, through ground containing boulders of various sizes, to bog. Many parts of the route are covered with thick bush and small trees.

In the cable-laying operations an advance gang will make a path through this scrub and blast the trench where solid rock occurs. A bulldozer will follow to clear the trench route ready for the trenching machine which is in the form of a mechanical shovel working backwards (a " back hoe "), picking up the earth and depositing it at the side of the trench. The drums of cable will be mounted on a tracked trailer which will be drawn by a tractor as the cable is paid off into the trench. A bulldozer will follow behind backfilling the trench.

From Clarenville, the shore end of the submarine cable will run along an inlet of the sea to Adeytown, where, at a point about 700 yards from the shore, it will be connected to a piece of one of the lengths of heavily armoured land cable, whence from this point normal land cable will run for about 5000 yards to the edge of the south-western arm at Hillview. H.M.T.S. " Monarch " will lay about 4000 yards of the same kind of cable across this inlet to Queens Cove. For the next 25,000 yards of the route normal land cable will be laid—that is, up to the first repeater position. At a point 4000 yards beyond, the main length of the heavily armoured cable will be laid by barge and tug along the bed of the Pipers Hole River (Fig. 1) for a distance of some 11,000 yards. Another 25,000 yard run of land cable crossing several lakes or " ponds " leads to the second repeater position and a further 27,000 yards beyond this point completes the land route. The cable terminates in the Terrenceville cable hut, where it joins up with the submarine cable to Sydney Mines.

Construction of the Land Cable

The central conductor of the Newfoundland cable (Fig. 2) is an annealed copper wire 0·1318in diameter lapped with three 0·0145in thick annealed copper tapes, bringing the overall diameter of the conductor to 0·160in. Over this conductor a covering of polythene is extruded in a single operation to a diameter of 0·620in.

Over the insulated core six annealed copper tapes 0·016in thick are laid, followed by a 0·003in annealed copper tape and then a rubber-bitumen-wax tape : up to this stage the land cable has the same construction as the submarine cable. The purpose of the 0·003in copper tape on the latter cable is to protect the insulation against the teredo worm. This tape is retained in the land cable to preserve uniformity of the electrical characteristics.

The Newfoundland cable may be subject to electrical interference from lightning, aurora borealis, electric power networks and radio. As a protection against lightning, wires will be laid above the cable in the trench to reduce the effects of a direct stroke or an induced voltage. As a protection against interference from other sources, one longitudinal and four spirally wound 0·006in thick soft iron tapes are applied to the core over which a rubber-bitumen-wax tape is lapped. To protect the soft iron tapes from rusting a polythene sheath 0·09in thick is extruded over the screened core.

The final stage of the cable construction is the armouring process in which a bedding consisting of two layers of tanned jute having opposite lays is first applied over the polythene sheathed core. Two kinds of armouring are employed. The normal type for the cable buried in a trench consists of 0·128in diameter galvanised steel wire. Where the cable is to be laid at the shore landings, across inlets, and along the river bed, a much heavier armouring is applied consisting of 0·276in diameter galvanised steel wires. Both kinds of armour are finished by an overall serving of two layers of tanned jute yarn with bitumen compound and finally whitewashed.

The overall diameter of the normally armoured cable is 1·75in, while that of the heavily armoured cable is 2·1in. The latter cable has been made in two continuous lengths, one of 5·7 nautical miles and the other 3·3 nautical miles. They will be laid by H.M.T.S. " Monarch " or a barge.

Cable Characteristics and Repeaters

The electrical characteristics of the cable have to be maintained with great uniformity so that the repeaters can exactly compensate the attenuation in all the cable circuits. Particular attention was therefore given to materials specifications and accuracy of manufacturing dimensions, especially the diameters of both the conductor and the polythene insulation, which had to be maintained within very close limits. Mechanical, magnetic and electrical control tests were applied to verify close conformity with the specified characteristics ; each completed length of cable was wound on its steel drum and immersed in water for several hours so that the final tests could be made at a known temperature.

Conductor resistance, capacitance and insulation resistance were first measured, followed by high-voltage insulation test of the insulation. To check the uniformity of the cable pulse-echo tests were applied, irregularities along the length being indicated by a cathode-ray oscilloscope (the irregularities must be small as the reflections they cause, in conjunction with the repeaters, may lead to degradation of the speech qualities of the cable). From this test the cable impedance was also determined.

The cable has been designed to transmit signals over a frequency band from 20 to 552 kc/s and attenuation measurements have been carried out over the working frequency ranges. To determine the characteristics of repeater sections, a number of lengths of complete cable have been jointed together and measurements made over the whole length to verify the cable characteristics and to see that they can be effectively compensated by the equalisers and repeaters.

The cable crossing Newfoundland will have two repeaters. Although they will be laid in the ground, they will be of the same type as those which will be used for the submarine cable linking Terrenceville and Sydney Mines.[1] They will amplify speech in both directions, the directional discrimination being secured by electrical filters responding to frequencies in the range 20 to 260 kc/s in the direction Terrenceville to Clarenville, and 312 to 552 kc/s in the reverse direction. The electrical equipment of the repeater is contained in a nitrogen-filled inner chamber which is separated by brazed-in bulkheads from the pressure-resisting outer housings. The cable is taken through watertight glands into the repeater chamber and the cable armouring is secured in clamps in the outer housings. Each repeater is provided with two 60ft tail cables which will be jointed to the land cable.

Bibliography

[1] Kelly, Gordon Radley, Gilman and Halsey : " A Transatlantic Telephone Cable." Abstracted in The Engineer, November 12, 1954, pages 678–681.

[2] " Manufacture of Transatlantic Telephone Cable," The Engineer, December 3, 1954, pages 775–777.

Improved V.H.F. Double-Tetrode Transmitting Valves

We have received some details of improvements that have been effected in the construction of Mullard double-tetrode transmitting valves to enable them to be used at very-high and ultra-high frequencies up to 600 Mc/s. In this connection it may be recalled that for high-frequency operation, the screen grid valve has the very important advantage over the triode that its anode-grid capacitance can be made very small ; in a typical tetrode or pentode this quantity may be one-hundredth that of a triode of comparable ratings. In high-frequency transmitters, tetrodes and pentodes may, therefore, be operated in conventional circuits without neutralisation. As the working frequency is increased, however, the effect of stray inductance in the screen and cathode circuits becomes marked. Inductance in series with the cathode gives rise to degenerative feedback, resulting in a lowering of the valve input impedance, which causes a waste of drive power ; inductance in series with the screen grid can give rise to positive feedback which may result in instability. Even when the effective length of the screen and cathode leads is made as small as possible by the use of short-lead decoupling capacitors connected at the valve socket, the self-inductance of the internal cathode and screen leads remains, and is sufficient to cause losses and instability at very high frequencies.

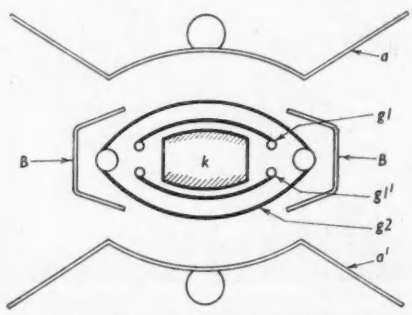
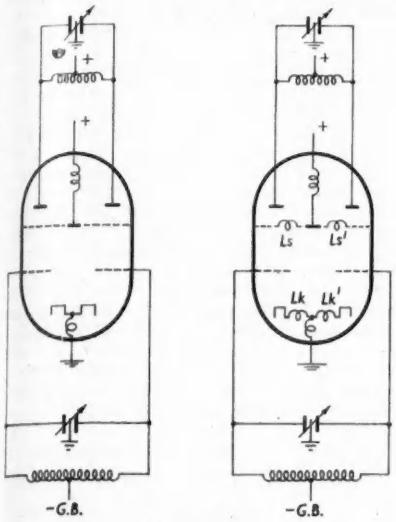


Fig. 1—Diagrammatic cross section through Mullard V.H.F. double-tetrode valve

An early remedy for this defect was to incorporate two screen-grid valves in one envelope, with the screens and cathodes connected together by low-inductance straps, the centre point of a strap being brought out as a pin connection. The two halves of the valve were operated in a balanced push-pull circuit, and since equal and opposite radio-frequency currents flowed in the common screen and cathode leads their inductances became unimportant. A typical circuit arrangement, showing stray inductance, is illustrated in Fig. 2. The existence of two separate electrode structures side-by-side in the envelope necessitated rather long grid and cathode straps, however, and these straps

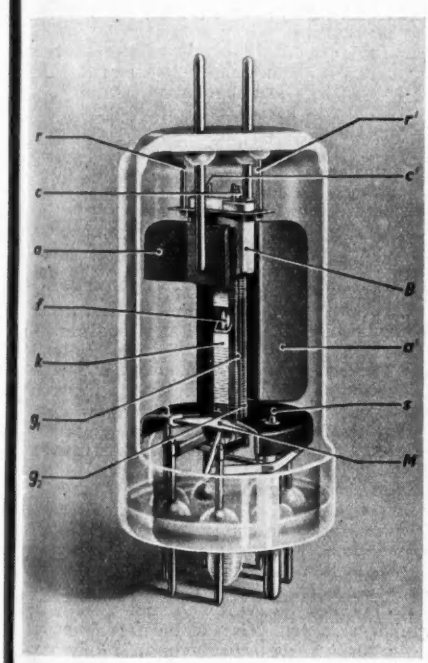
possessed sufficient self-inductance to cause undesirable feedback at still higher frequencies. At these higher frequencies, Fig. 2 ceases to be an adequate representation of the circuit, which becomes more like Fig. 3. The effects of *Lk*, *Lk'*, and *Ls*, *Ls'* are not cancelled by the push-pull connection.

In the new range of Mullard v.h.f. double-tetrodes an improved method of construction is used to reduce lead inductance as much as



Figs. 2 and 3

possible, and thus permit operation at frequencies as high as 600 Mc/s. This construction is illustrated in Figs. 1 and 4. It will be seen from Fig. 1 that use is made of a single indirectly heated cathode, which is roughly rectangular; only the long sides, which face the grids, are coated with emissive material. In effect, there are two separate cathodes, connected by the short sides of the rectangle, which act as very low inductance straps. A single screen grid is placed round both grid-cathode systems, eliminating the effects of screen-lead self-inductance.



r, *r'*—Electrode support rods.
c, *c'*—Neutralising capacitors.
a, *a'*—Anodes.
B—Beam plate.
M—Mica electrode supporting plate.
k—Cathode.
g_1—Control grid.
g_2—Screen grid.
S—Internal screen.

Fig. 4—Cut-away view of a Mullard v.h.f. double tetrode

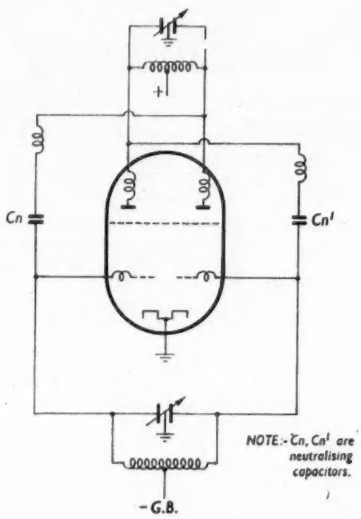


Fig. 5

In practice no screen decoupling capacitor is needed and the screen may be connected to its high tension supply via a choke or resistor.

Because this construction virtually eliminates the effects of screen and cathode lead inductance, the only remaining cause of instability at v.h.f. is the small residual grid-anode capacitance. It is possible for an amplifier to become unstable at certain high frequencies as a result of feedback through this capacitance. The effect is easily eliminated in a push-pull stage by connecting neutralising capacitors from the anode of each valve to the grid of the other. If, however, these capacitors are connected externally, the presence of stray inductance in anode and grid leads and the leads of the capacitors themselves has the effect of upsetting neutralisation at high frequencies. This effect is illustrated in Fig. 5, in which the stray inductances are indicated.

In Mullard v.h.f. double tetrodes, the effect of the grid and anode lead inductances in relation to neutralisation has been eliminated by incorporating neutralising capacitors inside the valve. These capacitors take the form of small pieces of wire (shown as *c* and *c'* in Fig. 4) connected to each grid support, each extending to a position near the anode of the other tetrode. The result is a direct electrical connection of electrode to capacitor without intervening stray inductance, and neutralising is effective at all frequencies.

The double tetrodes in this Mullard range include types QQV03–20A and QQV06–40A. The QQV03–20A (CV2799) has a maximum frequency (at full ratings) of 200 Mc/s, at which a typical load output is 39W under telegraphy conditions. At reduced ratings, an output of 15W can be obtained at 600 Mc/s. These figures assume circuit transfer of 80 per cent.

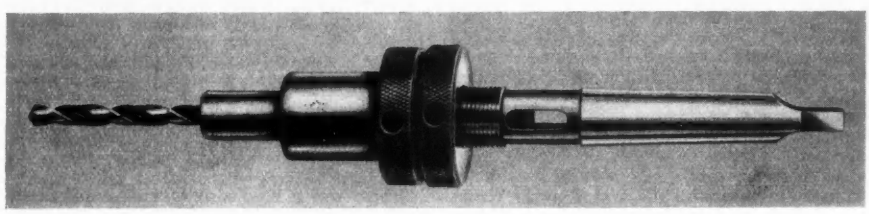
The QQV06–40A (CV2797) is a larger valve, with an anode dissipation of 20W per anode—twice that of the QQV03–20A. Under telegraphy conditions it gives at full ratings a load output of 72W at 200 Mc/s. With reduced ratings, outputs of the order of 45W at 500 Mc/s are obtained.

These valves have certain interesting constructional details apart from the special electrode configuration described above. They are made with envelopes of hard glass; the top and the base are of sintered glass, the use of which enables the anode seals to be preformed, and thus ensures the exact location of the anodes. Two short supporting members are also moulded into the glass top to locate the rest of the electrode assembly accurately relatively to the anode. These supports have the further advantage that they reduce vibration of the screen assembly and they are designed to produce no detrimental effects on the high-frequency performance of the valve. The anodes are of molybdenum coated with powdered zirconium, which reduces secondary emission, improves radiation of heat, and acts as a "getter" with the important advantage that its ability to absorb gases increases as the temperature is raised. The anode lead-out wires are made thick in order to reduce the adverse effects of self-inductance mentioned above.

A smaller, single-ended Mullard double tetrode has been developed for use up to 225 Mc/s. Some of the improvements described above have been incorporated in this valve (QQV03–10), which is a miniature all-glass valve on the Noval base. It has a rated anode dissipation of 5W per anode, and will deliver 10W output at 200 Mc/s (Class "C" telegraphy). It is intended to be suitable for use as an output stage for mobile equipments, and as a driver valve for the QQV03–20A and QQV06–40A.

Drill Holder and Setting Gauge

A COMBINED drill holder and setting gauge introduced by B.S.A. Tools, Ltd., Mackadown Lane, Kitts Green, Birmingham, 33, is intended for use with drills, reamers, counterbores or other tools with Morse taper shanks, and enables accurate drilling of component parts to preset depths. As can be seen from the illustration below of the holder, it is so designed that only the length of the cutting tool required for use is exposed, the remainder being shrouded in a bush, the lower face of which contacts the work and stops penetration at the predetermined depth.



Holder fitted with drill and with bush set to limit depth of drilling

The body of the holder has a Morse tapered shank and its lower part is bored to take the Morse tapered shank of the tool. The lower part of the body is threaded and a combined bush and knurled stop-nut through which the drill or other tool passes is screwed on to this part of the body. The distance the bush is screwed up the body is in accordance with the required depth of drilling. Once the bush is set it is locked in position by a knurled locking ring screwed down from above.

An adjustable setting gauge is supplied with the holder so that the required depth of drilling can quickly and easily be checked. The holder, bush and stop-nut and locking ring are normally threaded left-hand. This is a precautionary measure against the inadvertent failure, on the part of the operator, to lock the bush in place. In such a case the bush would tend to work down the holder where a normal right-hand rotation machine is employed, thus decreasing the drilling depth to avoid drilling to too great a depth.

SOIL ENGINEERING COURSE AT M.I.T.—A summer course in soil mechanics, applied to the construction of highways and airports, is to be held at the Massachusetts Institute of Technology during July. The course includes lectures on the various soil studies and design techniques of soil mechanics used for highway and runway construction, and also includes visits to laboratories and a constructional site. Further details may be obtained from the Summer Session Office, M.I.T., Cambridge 39, Mass., U.S.A.

Australian Iron and Steel Industry

BY OUR AUSTRALIAN CORRESPONDENT

At the time of the merger in 1935 of the two great steel manufacturing companies of Australia —the Broken Hill Proprietary Company, Ltd., and Australian Iron and Steel, Ltd.—the steel industry's production capacity had for many years been in excess of Australia's requirements. The country was then comparatively new to manufacturing and in the process of transition from industrial dependence on overseas to one of self-reliance. But the demands of the war greatly expanded the metal-using industries and the rate of expansion during the post-war years became in excess of the available supplies of iron and steel. For the past five years the iron and steel industry has been engaged on a major project of expansion and with the completion of the large new units of basic plant it is now becoming possible to keep pace with the rising demand. In many respects 1950 was a turning point in the industry, with large numbers of immigrants offering themselves for work and with greatly improved supplies of coal for both the B.H.P.'s works at Newcastle and the A.I. and S. Industry's plant at Port Kembla. One of the most important elements in the development programme of the industry has been the expansion of its collieries. About £A7,300,000 has been spent since the war in adding to the number of collieries within the group, in developing an entirely new colliery and in further mechanising and extending the remainder. This has raised its coal-producing capacity by as much as 40 per cent. For many years the steel industry has been the second largest consumer of black coal in Australia, requiring each year about one-fifth of all the black coal mined. It thus offers the coal mining industry the certainty of a steady future market.

Post-War Development Programme

In planning their post-war expansion projects, those responsible for the steel industry have had many problems to solve. It was one thing to decide that a major expansion should be undertaken, but it was much more difficult to decide which centres could be expanded with the greatest advantage and least cost and what particular forms the expansion should take. Considerable progress had already been made with the expansion of the Port Kembla Works into a large and well-integrated iron and steel plant, and during the early war years there were further additions to steel-making capacity. The seriousness of the war situation after 1941, however, put an end to further major plant expansion for the time being, the resources of the steel industry being given over entirely to the needs of war. The post-war period thus found the plant at Port Kembla still below its potential, and in some important respects, unbalanced. Its potentialities for further development had been heightened, however, in the intervening years. In the circumstances the directors of the company decided to continue with the building-up of the Port Kembla Works, making fuller use in the process of the ancillary facilities already available at that centre, and ultimately turning it into Australia's major producer of ingot steel. At no other centre of the iron and steel industry could productive capacity be raised more rapidly than at Port Kembla, a consideration which weighed heavily as the industry was faced with the necessity of increasing the supply of steel to Australian users as quickly as possible. Fortunately, land was available on which to erect large new units of plant. In the world setting, Australia is more than keeping pace with developments in other steel-producing countries of comparable size. Only Canada, among the smaller producers, has increased its steel-making capacity at rates substantially faster than Australia. Even so, Australia continues to occupy third place among British Commonwealth countries as a steel producer and her rate of expansion compares favourably with the United Kingdom, India and South Africa. At the present time, with an ngot steel-making capacity of 2,400,000 tons, Australia is fourteenth on the list of world iron and steel producers.

The Wide Strip Mill

The directors also took a second vital step. They decided to expand the range of the industry's activities to include the rolling of wide steel strip. It was a momentous decision, as it would involve the company in capital expenditure far exceeding that spent on any previous project. As a steel-rolling venture it would dwarf anything Australia had experienced in the past—moreover, it would take some time to complete. The wide strip mill had ushered in a major technological revolution overseas, particularly in America, where it had been developed during the 1930's, and where its advent had brought about a major advance in the rolling of flat steel products. Not only did the new mill make possible a much faster rate of production of wide steel strip and sheet ; it had also led to a lowering of their cost and thus a broadening of their uses. Its advent, therefore, meant that the industry could keep pace with the growing demand for durable consumer goods, such as motor-cars, refrigerators, washing machines, railway rolling stock, building materials, household effects and domestic and office furniture ; in all of which steel sheet is an essential component. Last, but by no means least, the demands of the canning industry for tin-plate had greatly widened the demand for large quantities of thinly rolled steel sheet. In the spectacular general increase in the demand for steel, no section of the market has grown more rapidly than that for steel sheet. Its applications are now so varied and so numerous that it has come to constitute a most important item in the industry's range of products. Flat steel products are in fact almost a symbol of the age in which we are living. It had become clear that the demand for steel sheet and plate products was likely to be a growing one, particularly in the light of Australia's post-war industrial expansion. Without facilities for rolling substantially larger tonnages, Australian users of plates and sheet would be greatly handicapped as time passed.

Tinplate

There was a need also to provide Australia with a tinplate industry. Like America, Australia is a large consumer of tinplate, its uses having increased with advances in food technology, with the broadening of dietary habits and the rise in the standard of living. Moreover, she is a food-exporting country and tinplate is widely used in the packing of perishable exports. B.H.P. for many years has had in mind providing Australia with a plant for meeting at least part of the local demand for tinplate, but the proposal had to be laid aside in the interests of more pressing matters. Australia's disadvantage in being without its own tinplate industry was driven home by World War II. Entirely dependent on overseas supplies, she was obliged to rely, to a large extent, on the United States as the war crisis deepened, the United Kingdom being unable to maintain her exports to Australia. With yearly demand averaging about 100,000 tons, and tending upwards because of the war, Australia was in a vulnerable position and, but for American aid, would have faced a serious situation. Between the mid-nineteen-thirties and the end of the war, the technology of the tinplate industry had undergone important changes and when B.H.P. once again revived its tinplate proposition, as a major part of its post-war development programme, events of the past decade or so made necessary a complete recasting of the plans of earlier years. Before the war B.H.P. had not contemplated installing a wide strip mill as a preliminary and indeed basic step in the production of thin steel sheets for tinning. After the war, however, in the light of trends abroad, it had become plain that the continuous wide strip mill must now be considered as an integral part of the proposition. As the supplier of mass produced sheet for the tinning line, it had become essential. Technological changes have thus transformed the scope of B.H.P.'s original idea. What in earlier years was a relatively simple proposition involving only tinplate, has widened to become the installation of a continuous strip mill, as well as a tinplate plant. The original idea has thus been transformed and in every way is much larger than the pre-war conception. Already the project has involved the industry in a capital expenditure of many millions. Part of the project is already in operation (the plate mill section), and the rolling of strip is expected to begin this year. The capacity of the plant is well over 1,000,000 tons of strip a year. The project itself, together with the installations ancillary to it—with ramifications throughout the length and breadth of the steel organisation—has been the largest capital work to date in the private sector of the economy undertaken by an Australian company. Its completion will mean that Australia is keeping abreast of oversea steel industry developments, and that the progress made in the past is being maintained. It is essential for the industry to keep in step with technological changes if it is to maintain its relative efficiency and a satisfactory cost structure. The wide strip mill has become increasingly prominent in other iron and steel producing countries since the war, and B.H.P. has seen to it that Australia has not overlooked this important technological advance.

Base of Industry Widened

The company's decision to install a wide strip mill meant, of course, that the entire base of the iron and steel industry had to be widened. The additional "feed" that would be required meant at least one new blast furnace as well as additional steel furnaces. These installations in turn make necessary an increased output of coking coal and of ironstone, extended transport facilities in the shape of additional ocean-going vessels, and railway rolling stock, more by-product coke ovens, heavier primary rolling mill equipment and more electrical generating capacity—to name only the more spectacular items. Equally important, it meant ultimately an improvement in the harbour facilities at Port Kembla. The expansion of the steel industry has proceeded on many fronts, and has taken several years to reach the final stages of what might be called the completion of its first post-war development plan. It has ranged over a wide field, extending from the iron ore deposits at remote Cockatoo Island, Yampi Sound, W.A., to the industry's coal mines in the vicinity of the Newcastle and Port Kembla Steel Works, and to its shipyard and ironstone workings at Whyalla. Often the expansion has been going on simultaneously at widely separated points around the Australian coast. It was logical that the industry should concern itself initially with the opening of new sources of raw materials. As soon as the exigencies of war had passed, work was resumed on the opening of the iron ore deposit at Yampi Sound, W.A., and the colliery development programme, particularly on the Southern N.S.W. field, was stepped up. A major reorganisation of the Southern collieries had been initiated in 1942, and after 1945 the modernisation of Bulli and Keira collieries proceeded. In addition, the entirely new Nebo colliery was opened in the district. Nebo first yielded coal in 1946 and following its development during subsequent years, has become Australia's most modern colliery, with a capacity of 3000 tons a day. The opening of new sources of other raw materials followed, including a dolomite quarry and loading jetty at Ardrossan, South Australia ; the further development of the limestone quarry at Rapid Bay in the same state (initially opened in 1942), and more recently the opening of a new bench at the Iron Monarch ore deposits. All these mining and quarrying developments were necessary if the industry was to produce substantially larger tonnages of pig iron and steel and provide in addition feed for the new flat products mill at Port Kembla, and the growing demand in Australia for all kinds of steel sections. In 1948 the foundations of a third blast furnace were poured at Port Kembla. The building of a second battery of Wilputte by-product coke ovens was also begun and by

1950, forty-eight of these were ready for firing. A further twenty-four ovens have subsequently been added, completing the battery and bringing it to a total of seventy-two ovens. Kembla's No. 3 blast furnace was blown-in in August, 1952. It is, by a wide margin, Australia's largest furnace, with a nominal annual capacity of 500,000 tons, but already it has produced well over its rated capacity. Its productive rate has been so good that recently it came close to breaking a world's output record ; it is in fact only surpassed at the present time by two blast furnaces in U.S.A.

"Dustuctor" System

We had the pleasure last week of attending a film show in London arranged by Holman Brothers, Ltd., of Camborne, to demonstrate the "Dustuctor" system of suppressing dust. The system has been developed from work originally undertaken to suppress dust produced by rock drilling in mines, work that led to the production of the "Dryductor" drill. For recording airborne dust produced by a drill a method was worked out in conjunction with the Inspectorate of Factories using cine-cameras and special lighting. The "Dryductor" system is based on the idea of working the dust away from the very source of its emission through a passage in the drill itself. That principle having been shown to be effective for rock drills, as one of the films very convincingly showed, the company turned its attention to the similar suppression of dust by working it away from the source of its generation by pneumatic chisels, grinding wheels and the like, and the films showed how successfully this adaptation of the system has been developed. Special chisels and grinding wheel hoods are now made in addition to filtering equipment to extract the dust from the air with which it is entrained. The system thus applied has been termed "Dustuctor," and we understand that the company is prepared to grant licences to any company which wishes to use the system for existing or contemplated schemes of dust removal and to undertake consultative work on the adoption of the system to suppression of dust and fines. One of the advantages of the system lies in the fact that relatively small quantities of air, moving at high velocity, are employed to entrain the dust so that large hoods and heavy trunking are not needed. It is claimed, and the films went far to support the claim, that dust is more effectively controlled than it is by conventional hoods. The development is particularly timely because in 1956 regulations come into force under the Factory Acts which make some means of dust suppression in foundries compulsory. The "Dustuctor" system, as we have mentioned, was initially applied to chipping hammers and portable grinders. Work is now proceeding upon its application to other tools and plant, the principles always being to collect the dust as close to the point of origin as possible and to build the equipment into the tool or plant. Surface grinders, bench grinders and swing grinders have all been successfully fitted. Much of the experimental work that led up to the development of the system has been recorded in papers presented before the Institution of Mechanical Engineers and the Institute of Mining and Metallurgy.

Protection of Structural Steel

The Corrosion Group of the Society of Chemical Industry held a symposium on "The Protection of Structural Steel" in London on March 31st and April 1st, under the chairmanship of Dr. J. C. Hudson, of the British Iron and Steel Research Association. Over 200 engineers, steel makers, steel users and paint and metal finish manufacturers and academic workers attended together with foreign delegates from a number of countries. About a dozen papers on corrosion protection were presented ; they covered good practice in painting structural steel, the performance of paints, research on corrosion prevention, the use of sprayed metal coatings, and protection problems in gasworks and chemical factories. Interest was shown during the discussions in the relative merits of paint and metal spraying protective techniques and particularly in the question of comparative costs. The testing methods employed in different countries were explained in detail by several of the foreign visitors, and the Society's spring lecture, delivered by Mr. F. L. La Que, of International Nickel Corporation (U.S.A.), dealt largely with American practice in this field. The Society's dinner was also held on March 31st at the Connaught Rooms. In proposing the toast of "The Corrosion Group," Mr. J. M. Leonard, president-elect of the Society, stressed the value of the Group's work in the four short years of its existence, and predicted for it a future of increased importance.

Indian Engineering News

FROM OUR INDIAN CORRESPONDENT

Soviet Steel Plant

An agreement has been signed in Delhi between the Indian and Soviet Governments for the construction of an iron and steel plant in India with an initial capacity of 1,000,000 ingot tons, or 750,000 tons of rolled products, designed for eventual expansion to 1,000,000 tons of rolled products. The plant, which is to be built in the Bhilai region of Madhya Pradesh, is to be in operation before the end of 1959, and some of its departments including three coke oven batteries, two blast furnaces, and two open hearth furnaces, are to be ready by December, 1958. The price is to be negotiated later, but it is estimated that the cost of the plant, machinery and equipment, excluding a sintering plant, will be about Rs.434 million (about £32,000,000). But as much of the plant as can be fabricated within the country will be locally procured. It is anticipated that it may be possible to fabricate up to half the plant in India. The total cost of the project, including township, railway sidings and mines, will be in the neighbourhood of Rs.1000 million, i.e. about £75,000,000.

The money will be payable in twelve annual instalments and the rate of interest on the amount outstanding each year is to be 2½ per cent per year. Repayment will be in rupees and will be freely convertible into sterling. A special account will be opened with the Reserve Bank of India, and part of the payment may be utilised for the purchase of Indian goods. The detailed project report is to be submitted within nine months. This will include the price of various categories of equipment that the Soviet Government is willing to supply. If the report is not acceptable, the Government of India reserves the right to terminate the agreement and reject the whole scheme.

The Government of India has undertaken, for the first time, to assume complete responsibility for preparing the works site, administrative supervision of the construction, erection and commissioning of the plant, labour relations, planning and construction of the township, fabrication of steelwork and supply of plant, machinery and equipment to the extent that capacity is available in India. The Soviet Government will provide a chief engineer and a team of experts who will perform the functions of consulting engineers and will be responsible for the satisfactory commissioning of plant as well as the integrated operation of the complete works for a minimum period of six months.

Part of the designing work and the drawings will be done in India. Indians will be associated at all stages of the work in India and in the U.S.S.R., the cost of training Indian personnel in the U.S.S.R. and of maintaining Soviet training instructors in Indian centres being borne by the Government of India. The Soviet Authorities will be paid Rs.25,000,000 (£2,000,000) for preparation of the detailed project report and the cost of the detailed working drawings.

Heavy Electrical Machinery

The Government has decided to set up a State-owned heavy electrical equipment factory at an estimated cost of Rs.200 million (£15,000,000). The location and other details of the project have yet to be worked out but it is understood that a preliminary project report submitted by the Associated Electrical Industries (Great Britain) and Siemens (Germany) will form the basis of the final project. The proposed factory will concentrate on heavy items, including transformers of 33kV and above, hydraulic turbines and generators, generators for diesel sets and traction motors for railways. The existing units at present engaged in the manufacture of light electrical equipment will continue and will be permitted to expand production if necessary.

The decision to set up such a plant will make India self-sufficient in most of the categories of electrical equipment she is now importing from abroad. By the end of the Five-year Plan, i.e. within the period of five years from 1952 to 1957, India will have spent over Rs.5600 million (£450 million) on her power projects, and it is estimated that at least a fifth of this sum will have been expended over the purchase of electrical equipment. Almost all the heavy machinery has come from Europe and America, Japan being represented mainly in such categories as switchgear, insulators and in one or two cases, as at Tilaiya, two 2000kW turbine and generator sets. Recently there have been attempts by the Soviet Union and her East European neighbours at marketing their goods here, but excepting Czechoslovakia, none of the other countries appears to have made any headway. The following table lists principal items of Indian electrical imports in the financial year ended April, 1954 :—

Class of equipment	1953–54, 1000 rupees	1952–53, 1000 rupees
Accumulators and parts	1,280	2,961
From U.K.	801	2,710
Batteries	1,531	1,684
From U.K.	673	1,197
From U.S.A.	689	1,031
Control and switchgear	56,974	54,836
Electric lamps	358	327
Electric lamps for automobiles	13	1,981
From U.K.	2	249
From U.S.	9	1,265
Electric condensers	527	557
Electric lighting accessories and fittings	4,973	4,997
From U.K.	3,133	3,855
Electrical goods, miscellaneous	16,933	22,305
From U.K.	10,032	13,348
From U.S.	3,328	3,876
Generators, alternators and dynamos	40,837	24,640
Motors	14,370	12,250
Meters	6,283	6,715
Radio apparatus	11,843	14,991
From U.K.	6,967	9,083
Transformers	19,424	15,425
Turbo-generator sets	7,652	12,984
Other electrical machinery	49,517	52,330
Wires and cables, including telegraph and telephone	67,070	72,416

Note.—Imports totalled Rs.331,005,000, an increase of Rs.9,540,000 over the previous twelve months. The United Kingdom retained about two-thirds of the aggregate trade.
1000 rupees = £75.

Atomic Energy

India believes that she has the largest and most advanced atomic energy programme among the nations of Asia. It is a "peaceful" programme, directed towards exploiting the atom as a source of power, and it is carried out under the control and supervision of the Indian Atomic Energy Commission. The Commission, which sponsors research projects in a number of educational and scientific institutions throughout the country, is a three-man body presided over by Dr. H. J. Bhabba, F.R.S., and reporting directly to the Prime Minister. The leading nuclear research centre in India is the Tata Institute of Fundamental Research at Bombay, which is looking into the possibilities of producing heavy water and building a nuclear reactor. The construction of the nuclear reactor at Trombay, about 20 miles from Bombay, is expected to be taken in hand very soon and completed by early 1957. The reactor, according to the Commission, would be an experimental one, using natural uranium from sources available in the country. The cost will be about Rs.10,000,000 (£750,000), and the monazite sands in Travancore-Cochin are being processed for the purpose.

A plant for the production of heavy water is to be set up near the Nangal dam in the Punjab, according to the Ministry of Production, the capacity being between 5 tons to 7 tons annually. At present, heavy water is either being imported or proposed to be imported from the United States, with which an agreement has just been entered into for its supply for experimental purposes. Details of the plant will be worked out in conjunction with British experts whose services, it is hoped, are to be made available through the Colombo Plan.

THE ENGINEER

Vol. 199 APRIL 15, 1955 No. 5177

LEADING ARTICLES—
Pursuit of the Useless ... 526
Pressure Cabins in Aircraft ... 526

ARTICLES—
Applied Mechanics. No. II ... 513
Australian Iron and Steel Industry ... 524
Band Sawing and Filing Machine. (Illus.) ... 535
British Steel Plate in North America. (Illus.) ... 536
B.S.R.A. Resistance Experiments on the "Lucy Ashton." (Illus.) ... 531
Catalogue of Early Motor Vehicles ... 509
Damodar Valley Project, No. III. (Illus.) 510
Drill Holder and Setting Gauge. (Illus.) ... 523
"Dustuctor" System ... 525
Improved V.H.F. Double-Tetrode Transmitting Valves. (Illus.) ... 522
Institution of Naval Architects. No. II. ... 528
Institution of Naval Architects' Annual Dinner 509
Iron and Steel Institute ... 515
Locomotives for Sub-Arctic Railway. (Illus.) ... 537
Lubrication of Tractors ... 509
Overland Link in Transatlantic Telephone Cable. (Illus.) ... 521
Precast Concrete Structural Assemblies. (Illus.) 534
Protection of Structural Steel ... 525
Side-Operated Fork-Lift Carrier. (Illus.) ... 530
Spraying Machinery for the Colonies ... 509
Stresses due to Shearing Forces in a Holed Plate (Illus.) ... 518
Survey of Inland Waterways ... 509
Terminal Buildings at London Airport. No. III 520
Travers Irrigation Dam, Alberta. (Illus.) ... 536
Uganda Electricity Board ... 509
Wheatstone Bridge for Two Systems of Units. (Illus.) ... 516
625 h.p. Diesel-Hydraulic Locomotives. (Illus.) 535

AMERICAN SECTION—
Super-Critical Steam-Electric Power Station (Illus.) ... 538
First International Congress on Air Pollution ... 540
United States Ten-Year Highway Plan ... 540

LETTER TO THE EDITOR—
Reports from the Footplate ... 528

LITERATURE— ... 527
Books Received ... 528

OBITUARY—
J. E. Lea ... 527

NEWS AND NOTES—
British Patent Specifications. (Illus.) ... 543
British Standards Institution ... 544
Forthcoming Engagements ... 544
Indian Engineering News ... 525
Industrial and Labour Notes ... 541
Launches and Trial Trips ... 542
Personal and Business ... 542
Technical Report ... 519

THE PURSUIT OF THE USELESS

There is a surprising tendency in the human mind peculiarly to admire the pursuit of what is useless. This tendency stems, perhaps, from a past age when the fact that a man could afford to pursue knowledge for its own sake signified, like the long finger nails of a Chinese mandarin, that he had no need to work, must therefore be wealthy and must also be near the top of the social scale. Relics of this once much more common method of appraising the worth of human beings can be traced to this day. Pure scientists, for example, enjoy, in social esteem, a higher status than applied scientists so that, though, to-day, there is a serious shortage of technologists, it is the pure sciences that are over-stocked with students at the universities, not the technologies. Again, there was a time when "Art for Art's Sake" was the only pursuit worthy of a true artist; and applied art was regarded as a lower and less respectable activity. Perhaps, amongst students, the myth persists. We do not know. There is, too, the same air of respectability about those who have a ripe knowledge of the classics, though nowadays they need to justify their choice of education by claiming that it helps them the better to understand human nature! Thus, even in this workaday age when there are very few left who retain enough wealth to be able to get along without working for money, the old idea still lingers on: so that the workaday fellow, concentrating upon some useful job, without the doing of which civilisation as we know it to-day could not survive, feels ashamed to admit to a lack of knowledge of Homeric lore or to reveal abysmal ignorance of history and an inability to appreciate the "best" art. Yet, by contrast, though not one of these cultural attainments can contribute to the material enrichment of a country, those who have acquired them often seem quite unashamed to confess to a total lack of understanding of science and no interest whatever in technology!

Monetarily, though only with a rougher kind of justice, our civilisation has learnt to value a man by what he does; but socially it continues to appraise his status by the level of his less useful knowledge. However brilliant a man may have proved himself at designing aircraft, raising production in a factory, administering a great engineering works, or building great dams and bridges, he will still be regarded socially as of little account (and his salary is likely to suffer thereby!) if he has never heard of Tacitus and Apuleius, looks blank at a mention of Sir Thomas Browne, knows little of Shakespeare and less of Chaucer, cannot distinguish between a Rubens and a Rembrandt, has never heard of pre-Raphaelites, is hazy about the styles of Gothic architecture, and quite unable to discuss the works of modern authors, playwrights, artists and architects. Nor is society wholly wrong in making this distinction. For, paradoxically, though the system may have developed in the past with the snobbish object of distinguishing between the wealthy and well-born who had no need to work and all the rest, it preserves, to-day, when neither great wealth nor great poverty exists and birth and breeding count for little, the virtue of stressing that the mere material enrichment of mankind is not the be-all and end-all of human existence. The materially worthless knowledge by which the social standing of a man is measured expresses itself as an appreciation of the graces and the æsthetic aspects of life. Unlike material advances that can only make life more comfortable, it contributes to make it more enjoyable. It is, in fact, knowledge that men need to acquire and will enjoy acquiring, if life is to be fully savoured; and it is the more regrettable that university and college syllabuses, overflowing with technical studies that an engineering student must master, leave little room for the continuation of cultural studies which were begun in school.

But the thing is often pressed too far! Particularly is it pressed too far when it is blandly assumed that culturally a man has no pressing need for an understanding of science. How strange it will seem to historians of a future time looking back upon this, an age whose culture is not only supported by, but permeated, through and through, by influences from science and its applications, that man could still hold science as inessential to a general cultural education! For in many fields as, for example, the design of aircraft, dams, superlatively light concrete bridges and other structures, power stations, ships and many other things engineers are often not merely influencing architects and artists by their discoveries but guiding their advance by showing how the application of scientific principles and the economic use of materials leads naturally to æsthetically satisfying results. Again the thing is pressed too far when it is assumed, by those who have never experienced it, that an engineering education, with its concentration upon science and technicalities must necessarily unfit a man for administration. What nonsense! Henry Ford, it is recorded, said "History is bunk"—a most deplorable remark! His opinion of a classical education is not recorded, but may well be imagined. Yet his ability and his knowledge of human beings permitted him to build up and administer an immense and complicated industrial empire. What is needed in an administrator is good sense, leadership, the power of logical thought and a knowledge of human nature. Those are qualities that an engineering education, academic and practical combined, is well-adapted to develop.

PRESSURE CABINS IN AIRCRAFT

Recently the lay press has revealed some doubt on the part of the public whether the provision of "pressure cabins" may not be a wasteful addition to the load normally carried by an airliner and whether it might not be better to employ oxygen masks, or the like, when high-altitude flying is an important objective. Certainly a pressure cabin does increase the weight, but it may well be questioned whether the alternative suggested would not add just as much, besides being vastly less convenient to passengers! It was natural that the possible use of pressurised cabins should be considered first for military aircraft, since it was those craft that first undertook as normal practice long flights at high altitudes. It was not necessary to aim at any considerable differential pressure, since the first 10,000ft in altitude are hardly felt, and stresses in the cabin shell could therefore be kept within modest limits. But it was realised, of course, that there was a chance of severe internal damage to the human body should there be any sudden decompression such as might be the consequence of an anti-aircraft projectile exploding near enough to break the cabin skin. In that event, the pressure in the lungs must suddenly become several pounds per square inch higher than that outside. Militarily, of course, that was one of the possible mischances in war that had to be faced. Decompression could also occur through the bursting of the aircraft skin, if it proved not strong enough to meet all eventualities, including the risk of failure through fatigue.

But if for any reason accidents of that kind did happen in military aircraft, they were, for security reasons, little reported in the press and so remained unknown to the public. In the course of time, however, the merits of flying at heights of 20,000ft and over became highly attractive to the civil airline operators. For it enables passengers to enjoy the advantage of flying "above the weather," and provides a safer and less bumpy journey. Of these advantages the immediate popularity of flying in the "Viscount" was evidence enough.

But when "unexplained" accidents occur in civil flying they are likely to lead to public inquiry and so become highly publicised. Immense interest, for example, was taken in the inquiries into two accidents to "Comet" airliners. The report of the inquiry clearly established that the accidents, with their regrettably heavy loss of life, must be attributed to explosive decompression, and it was reasonably surely shown that the failure started in fatigue cracks close to one of the cabin windows. Engineers have long been accustomed in their professional work to employ "factors of safety" which experience has shown to be desirable. These factors are usually large enough to cover the cases of exceptional loading conditions as well as allowing for a certain amount of uncertainty in determining the stresses likely to be incurred in normal usage. Years of experience have shown the wisdom of adopting a conservative policy in choosing factors, which to the layman sometimes seem unexpectedly large. For crane ropes a safety factor of 5 or 6 is usual, and in steel girder bridges the figure may be almost as high. One of the uncertainties covered by these factors—though those who laid down in the past what was and what was not good practice probably were unaware of the phenomenon—is the effect of metal fatigue where stresses fluctuate frequently. In aircraft design it is, of course, important to aim at as low a weight factor as is possible. Stresses and strains are therefore computed more completely and factors of safety can, accordingly, be made smaller. But as we pointed out in these columns in our issue of February 25th last, although normal strength requirements call for pressure cabins to withstand twice the normal working pressure-differential, the "Comet" cabin designers, for additional safety, worked to a figure 25 per cent higher still. Even so, as has repeatedly happened in the past and will again happen in the future, the factor proved too low to cover the real working conditions. Lessons were learned that will affect the design of all future pressurised aircraft. It is, however, worth observing that modern civil aircraft probably have longer lives than their predecessors and that they are therefore proportionately more liable to suffer from the fatigue arising out of repeated changes in the stresses to which they are subjected. Furthermore, not only do they have to encounter the frequent air gusts common at low altitudes, but also the high velocity jet streams and associated turbulence that has recently been found to exist at high altitudes of flight.

It has become particularly noticeable lately how often aeronautical design raises novel problems in metallurgy. A striking instance arose, of course, in the design of turbine blades for jet engines, wherein allowance was found to be necessary for a quite unusual combination of very high temperatures with considerable mechanical stresses. In the "Comet" investigation an equally striking instance of the occurrence of metallurgical factors of an unusual and unexpected type was revealed. In this aircraft the cabin sheeting was of aluminium alloy, and, as Sir Arnold Hall has pointed out, in a lecture to the Institute of Transport, it happens that in some aluminium alloys it is found that subjection to a high temperature can promote precipitation of alloying atoms, and produce a soft matrix of practically pure aluminium in which are embedded large aggregates of precipitates. Any soft spots so created may be extended by an alternating stress and a dangerous fatigue crack result. It is evident that designers of pressure cabins will need to study with great care the results of current work in laboratories engaged in such metallurgical research. But that the public will wish to continue to enjoy the advantage of flying in such cabins is equally evident.

Obituary

J. E. LEA

We record with regret the death of Mr. James Edward Lea, M.I.Mech.E., chairman and founder of the Lea Recorder Company, Ltd., which occurred at Southport, on April 3rd. Mr. Lea, who was in his eighty-seventh year, was born at Sandbach, Cheshire. and was educated at the Sandbach Grammar School and at Parkhurst College, Buxton. From 1883 until 1889 he served an apprenticeship with Edwin Foden and Co., Ltd., Sandbach, on completion of which he worked for a short time at Tangyes, Ltd., Birmingham, and at Cammell Lairds Shipyard, Birkenhead. In 1891, Mr. Lea entered Owen's College, Manchester, where he won a Whitworth Exhibition, and in 1894 graduated with a B.Sc. degree in engineering. He then went to Glasgow for some electrical experience, and subsequently served as third engineer on two steamships, which took him to the Middle East and America, respectively. In 1895, he sailed for South Africa, where for a time he joined his brother on his farm at Brereton in the Transvaal. But Mr. Lea soon returned to the engineering profession, and took charge of a mining company's drawing office in Johannesburg for three years.

In 1902, Mr. Lea took up an appointment with the East Rand Mines at Johannesburg. There he began making use of a vee-notch for the purpose of measuring water, the method being adopted in various mills and used for both boiler tests and for measuring water supplies. At the same time, Mr. Lea was perfecting his first automatic recorder which had a formula cam in the form of a spiral wire soldered to the outside of a cylindrical drum, and on which a saddle was carried to move the pen mechanism. In 1905 he took out patents for the recorder, and returned to England to begin its manufacture. In 1913, the Lea Recorder Company, Ltd., was registered as a limited company, and in the same year Mr. Lea went to America to arrange for the manufacture of his recorder there under licence. From then onwards, Mr. Lea's energies were devoted to the company which he had founded, and until comparatively recent years, he used to spend several hours a week in the works. Mr. Lea continued to serve as chairman of the company up till the time of his death.

Literature

Gas Turbine Principles and Practice. Consulting editor, Sir Harold Roxbee Cox. London: George Newnes, Ltd., Tower House, Southampton Street, Strand, W.C.2. Price 90s.

This lengthy and comprehensive book is a useful addition to the rapidly growing volume of literature on the gas turbine. It endeavours to cover all aspects of the subject, and comprises some thirty sections, each written by a specialist, under the general editorship of Sir Harold Roxbee Cox.

The sections fall into four main groups: those in the first group deal with general topics applicable to all types of gas turbine, namely, gas turbine cycles, thermodynamics, mechanical design, materials, stress and vibration. The second group consists of articles on the design of particular components—axial-flow turbines, radial-flow turbines, heat exchangers, &c. There are eight sections devoted to fuels and combustion, including the design of combustion systems and the important problem of ash deposition. Liquid and solid fuels are dealt with by separate authors. Gaseous fuels are not considered in any detail. Finally, there is a group of seven sections discussing the various applications of the gas turbine.

The authors are all recognised authorities in their respective fields, and, moreover, share the ability to write in a clear and interesting manner on their chosen subjects. The text is illustrated by excellent diagrams, sectional drawings and photographs.

The design of the book, whereby each aspect of the subject is dealt with by a different author, enables a high technical standard to be attained throughout, but has the corresponding disadvantage that it is not easy to achieve unity of treatment, or to prevent overlapping or omissions. For example, descriptions of positive displacement compressors, free piston type gas generators and similar items are repeated in the articles on gas turbine cycles, thermodynamics, and the mechanical aspects of design. Similarly, jet engine cycles are dealt with under aircraft applications rather than under gas turbine cycles, while methods of determining gas turbine cycle performance form the main content of the chapter on thermodynamics.

At the present stage in the development of the gas turbine there are many aspects of design on which widely differing opinions are held. While generally speaking the authors attempt to maintain a fair balance in such cases there are times when a strongly held personal opinion results in an author presenting a rather one-sided picture. An example is the strong advocacy, in the section on mechanical design, of the single or two-stage turbines with air cooling, as opposed to the uncooled multi-stage design.

On the question of omissions, one would have thought that liquid cooling of gas turbine blades merits more than the passing reference it receives. While this system is admittedly not yet in service a great deal of work has been and is being done on the problem, and there is no doubt that it is of enormous importance for the future development of gas turbines. Similarly, although ash deposition in turbines is dealt with in some detail, it is surprising that the subject of vanadium attack, which is of equal importance in the use of residual fuels, is barely touched on. Throughout the various articles there are very few references to weights and costs and no reference to testing or instrumentation.

The sections dealing with gas turbine applications are of much interest. The air-

craft application is dealt with very fully, but the stationary, marine and transport applications are less detailed. In particular, the section dealing with marine applications tends to give too narrow a picture of the present situation. The special prominence given to the closed cycle gas turbine is out of proportion to the work being done in Great Britain and the rest of the world. Most makers of marine gas turbines in Great Britain would offer the open cycle type of machinery.

In spite of these comments on points of detail, the majority of the book is of a high standard, the design sections being particularly useful. The book can be cordially commended, both to those beginning a study of gas turbine principles and practice and to those wishing to extend their knowledge of the subject.

Letter to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

REPORTS FROM THE FOOTPLATE

SIR,—In adding to the welcome given to Dr. Tuplin's refreshingly new approach, showing, moreover, that the scientific mind yields nothing to the lay in imagination, I suggest that in future instalments the horse's mouth should be located on the C. de F. Ruritaniale and avoid the element of doubt arising from the introduction of unrecognisable British Railways factors.

When did Dr. Tuplin see a main line engine at King's Cross pick up three extra coaches, and where would it find them ? Why should an "A4" driver go outside to wipe mud off the windows instead of opening them and cleaning from inside ?

In Dr. Tuplin's land of faery imagery a fireman apparently counts numbers between shovelsful for hours on end ; why not give him one of those timers extensively used with pressure cookers, which would also ring a bell ?

More seriously, if Dr. Tuplin observed an experienced driver and fireman on a Gresley "Pacific" or "V2" he would find little worry with the regulator, nor would the driver ask the fireman to shout to him about water level. He can see it and control one injector without leaving his seat and so relieve the fireman of water watching when firing is strenuous. This facility has been lost on B.R. designs by placing both injectors on the fireman's side without perceptible advantage.

L. A. FULLAGAR

Whetstone, N.20.
April 4th.

Books Received

Microbes and Us. By H. Nicol. Middlesex : Penguin Books, Ltd., Harmondsworth. Price 2s. 6d.

Fifty Years of Western Express Running. By O. S. Nock. Bristol : Edward Everard, Ltd., 38, Broad Street, Bristol. Price 25s.

Circuits and Networks. By Glenn Koehler, London : The Macmillan Co., Ltd., 10, South Audley Street, W.1. Price 45s. 6d.

Manufacture and Application of Lubricating Greases. By C. J. Bower. London : Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 148s.

Electric Railway Engineering. By T. Ferguson. London : Macdonald and Evans, Ltd., 8, John Street, Bedford Row, W.C.1. Price 57s. 6d.

Radar Pocket Book. By R. S. H. Boulding. London : George Newnes, Ltd., Tower House, Southampton Street, Strand, W.C.2. Price 15s.

Jet Engine Manual. By E. Mangham and A. Peace. London : George Newnes, Ltd., Tower House, Southampton Street, Strand, W.C.2. Price 10s. 6d.

Introduction to Theoretical Mechanics. By R. A. Becker. London : McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 57s. 6d.

Institution of Naval Architects

ANNUAL SPRING MEETING

No. II—(*Continued from page 495, April 8th*)

THE annual general meeting of the Institution of Naval Architects was held on the morning of Wednesday, April 6th, when the secretary read the annual report of the Council for 1954, which recorded that Mr. E. L. Champness, M.Sc., and Sir Charles Lillicrap, K.C.B., D.Sc., had been elected to be honorary vice-presidents in recognition of their long and valuable services. A further small increase in the membership was noted, the total number on the roll at the end of 1954 was 3728, which represented an advance of sixty-nine over the previous year.

Dr. G. Hughes, D.Sc., Ph.D., was awarded the Gold Medal of the Institution for his paper "Friction and Form Resistance in Turbulent Flow and a Proposed Formulation for Use in Model and Ship Correlation," and in recognition of his previous work on "Skin Friction Resistance." A premium was awarded to Lieut.-Commander J. N. Bathurst, O.B.E., D.S.C., R.C.N., for his paper on "Underwater Television," and Mr. Raymond Adams, of Robert Gordon's Technical College, Aberdeen, was announced as the recipient of the Duke of Northumberland Prize. Awards of National Certificates in Naval Architecture were recorded, the number at ordinary level was 126, and represented a considerable increase over 1953, while the total of twenty-nine higher level certificates was a considerable reduction from the total of the previous year.

The first prize of the City and Guilds of London Institute's final examination was won by Mr. T. S. Ferguson, but no second prize was awarded this year. Mr. T. L. Mackie, received the Watts Prize for his paper "Shipborne Pests and a New Insecticidal Treatment," while for his work in connection with the Tonnage Measurement Laws Committee and the Merchant Shipping Act, 1954, Mr. J. W. Thurston was awarded the Samuel Baxter Prize. The activities of the Southern Joint Branch were recorded and also that Mr. J. A. Milne, C.B.E., had been elected president. The inaugural dinner of the Australian Branch was recorded and an announcement made to the effect that the Institution of Naval Architects' Elgar and Martell Scholarships had been amalgamated and would be awarded in alternate years. Mention was made in the report of the unveiling of the William Froude Memorial at Torquay and also of the presentation of a further memorial tablet for erection in the main entrance to the Town Hall.

The report listed the donors of equipment for the Weir Lecture Hall and noted that Armorial Bearings has been assigned to the Institution by the College of Arms. The issue of the Scott Catalogue was noted and the fact that Mr. K. C. Barnaby, B.Sc., had been asked to prepare a history of the Institution in preparation for its centenary in 1960. Brief summaries were included in the report of the main items of research which form part of the programme of the Ship Division of the National Physical Laboratory, the British Shipbuilding Research Association, Pametrada, and the British Welding Research Association. Particulars of scholarships awarded in 1954 were listed, together with those offered for competition in 1955, and the report included a financial statement which was presented by the treasurer, Rear-Admiral Sir Arthur E. Hall.

PRESIDENTIAL ADDRESS

Following the reading and adoption of the report, Viscount Runciman gave his presidential address, of which an abstract follows.

This last year has been one wherein nothing particularly spectacular has happened in naval architecture, but wherein there has been a very considerable amount of progress in a good many directions. Moreover, it has been a year in which the outlook for shipbuilding has appeared rather more hopeful towards the end than perhaps it did at the beginning, and from one point of view also, that is to say, in the state of the order books for merchant ships and, indeed, in the amount of naval construction, both completed and on hand, the year was perhaps a little better than the one that went before.

The Royal Navy completed over the past twelve months quite a large number of ships, and a considerable amount of work has been done and progress can be recorded on improving living conditions for those who have to serve in very large numbers and in rather small spaces in Her Majesty's ships. There has been considerable progress in trying to reduce the cost of maintenance in the Navy, experiments are going on in connection with the cathodic protection of ships in the Reserve Fleet which should effect considerable economies over a period. The Navy is experimenting also on the use of plastics for small craft.

On the merchant shipbuilding side there is a higher proportion of dry cargo tonnage on the order books which seemed at one time to be filled very largely with orders for tankers. Whether that means that the number of tankers in the world is getting somewhere near what it ought to be, that the leeway has been made up in tanker construction, I do not know.

On cargo ships one notices with sadness the relative decline in tramp tonnage flying the flag of this country, and with some slight apprehension in observing the flags of countries we do not normally associate with the operation of a large mercantile marine. I do not propose to weary you with a disquisition on either of the two topics which agitate the minds of shipowners particularly at the present time, namely, discrimination against the free use by shippers of tonnage under any flag which they think suits them at any time, in order that certain countries not naturally very well qualified to own or run ships may increase their mercantile marines, and the increasing use of what has come to be known as "flags of convenience." These are both matters which directly affect shipowners and indirectly may to some extent affect shipbuilders.

What will certainly affect British shipbuilders, and indeed has already begun to do so, is direct foreign competition in shipbuilding. It is easy for the shipowner to say that all you have to do is to get your costs down. Obviously the British shipowner will place his orders in British yards if he can possibly do so, but it is important that the temptation to him, whether on price or delivery, to place his orders abroad does not become overwhelming. How those costs are to be brought down it is not for me to say, except perhaps to remark that so far as the outside observer can distinguish between the more expensive yard at home or abroad

and the less expensive yard at home or abroad, a good deal of the difference seems to lie in the facility with which the steel and the prefabricated work is actually brought alongside the berth and set up for inclusion in the vessel. That raises a number of difficult and complicated problems, problems of site, of layout, of turning a whole yard upside down in the hope that it may be better afterwards. I have no doubt that the costs of labour and steel are likely to remain at least as high as they are to-day and may possibly become higher. A real economy is to make quite sure that the labour and material are brought together and made into a ship with the smoothest possible flow and the least possible interruption and delay.

The continuing and interesting developments in propulsion are the use of the gas turbine and behind it the use of atomic energy. It is fairly clear that any great development in either may well bring in their train certain developments in the actual design of the ships which are to contain such machinery.

There are two points, one in connection with each of these forms of propulsion, which are becoming rather surprisingly of immediate interest ; these are the effects upon the health of those who will be associated with power plants of this character, and the fuels. We know the things that have to be guarded against in the use of atomic power and radiation. What is not so generally known, but is beginning to be rather unpleasantly discovered, is the effect upon health of the vanadium components which are now coming into fuels, particularly for gas turbines ; that may well become a serious problem if it is not carefully watched. It seems to me that that must in turn lead to some matters for consideration from the purely naval architecture viewpoint in the design of the ships so as to assist in any methods which may be adopted for keeping that sort of thing under control.

This last year has been one of steady, but not spectacular progress, and it is extremely improbable that we shall find in that art or science any really revolutionary change such as will put every existing ship out of date in a fortnight. We are more likely to pursue as steadily as we can our search, not for the perfect ship but for the best compromise in trying to find it.

* * *

On the morning of Tuesday, April 5th, Dr. S. Livingston Smith, C.B.E., presented the first paper of the meeting. This was entitled, " B.S.R.A. Resistance Experiments on the 'Lucy Ashton.' Part IV—Miscellaneous Investigations and General Appraisal," and an abstract of the paper is printed on page 531 of this issue. In addition to reading the paper, Dr. Smith showed a film of the ship when taken out for " nursery " trials to check equipment and the controls.

Discussion

Dr. R. W. L. Gawn : This concluding paper brings home the extent of the debt we owe to the British Shipbuilding Research Association. The famous report of the British Association for the Advancement of Science presented as long ago as 1869 emphasised the need for reliable resistance experiments on ships with all relevant measurements and precautions. Despite the lapse of time, very few trials have been carried out.

The key to reliability was the ingenious conception of jet propulsion. Probably the most valuable of the many results is the substantial vindication of Froude's law for residuary resistance and of the method of predicting the resistance of shaft appendages from model tests. The improvement effected by careful attention to surface finish should stimulate further developments on ships in this respect. No skin friction formulation has been found to be completely satisfactory throughout the speed range for all sizes of model but this reflects on the complexity of the problem. The investigation has brought out that the complications are even deeper than formerly supposed. Nevertheless, the margins have been clarified. The author's views would be appreciated on the wisdom of consistency as to size of model and procedure for predictions generally. This has been a corner-stone of practice pending further knowledge to broaden our foundations. The extension of the investigation to larger ships which the author envisages is one most commendable step in this direction. In my view, developments in naval architecture have reached the stage when we can no longer afford not to afford the large expense involved.

With regard to the new results in the paper, Fig. 5 indicates a marked increase of resistance due to fouling, but this is not surprising as the ship was stationary between trials and no precautions were taken to limit marine growth. The lower rates of increase quoted from Admiralty experience are confirmed. As bearing on the trend of modern practice, it may be mentioned that one recent trial with a large ship three-and-a-half months out of dock indicated a daily average increase of skin friction resistance of only $^1/_{12}$ per cent. The daily rate is evaluated as guidance for estimating service performance when a ship is as much as six months or more out of dock. The " Lucy Ashton " trials covered only a bare two months, but even so the rate of increase of skin friction fell off in the final weeks and was then fairly linear and ultimately about $\frac{1}{4}$ per cent per day. The germination period of about two weeks revealed in the diagram hardly affects the estimate of a daily average after several months in service, particularly with modern compositions. No real inconsistency is therefore involved in the conception of a daily rate.

Fig. 12 will be helpful in dealing with manœuvring and surging problems. A stopping trial was carried out on a destroyer a few years ago with the propellers locked and a virtual mass coefficient of 15 per cent was deduced. The length constant of the ship was 8·29, so the spot is above the author's curves. The difference seems rather larger than can be attributed to the difficulties of deducing the coefficient. The large resistance of the propellers may be a factor, but speed and other parameters may be involved, although perhaps to a less extent than length constant. The results of the investigation on small models in the Trondheim tank, published in 1954, confirm the importance of length constant, but the effect of speed was apparent.

Professor G. Aertssen : Concerning the effect of fouling on resistance, the high figures obtained after twenty-four days out of dock (2 and 1 per cent increase in skin friction) would certainly have been much lower had the ship been in service. The " Lucy Ashton " results concerning the effect of fouling cannot be extended to commercial ships because this ship was not operating under normal commercial conditions.

Even for a ship in normal commercial conditions it is very difficult to obtain general figures. It is useful to have separate figures for temperate and warm waters, but more is involved. There is the speed of the ship and the ratio of the time in harbour to the time of navigating. The Victory ship " Tervaete " came out of dock, sailed to India and East Africa, where she spent a long time in harbour and came back to Antwerp after three months with an increase of resistance of more than 20 per cent. After that she was engaged in the service Antwerp-New York-Congo-New York-Antwerp, and she showed no appreciable increase of resistance up to the time she was dry-docked a year later. Tropical harbours are fouling, and harbours in a bay are much more so than harbours on a river. The M.V. " Lubumbashi," with her 15 knots, sailed on the line Antwerp-Congo-Antwerp ; the increase of resistance was 9 per cent after six months service and was estimated at 12 per cent after a year. The increase is not linear, and that is confirmed by the " Lucy Ashton " experiments.

Concerning the pitot traverses in the friction belt, there is good correlation between the loss of momentum given by the velocity curves and the measured increase in skin friction due to fouling. This is stimulating for ships' officers, when there is a pitot log on board with extensible rodmeter, to take the velocity curve frequently in order to try to detect an occasional increase in skin friction. The author states that " whereas reasonably steady readings could be obtained when the log was set in the fully extended position, it was often difficult to obtain satisfactory readings when traversing through the boundary layer. For this reason, many of the records taken have to be discounted in view of unacceptable fluctuations in the observations." How long did the experimenters wait between successive readings ? The instrument has a great inertia and it needs time before the mercury column and the needle find their new position. We had a pitot log on the " Tervaete," and the " Lubumbashi " and, when making a pitot traverse, we had often to wait between 3 and 5 minutes before taking a reading. A pitot traverse in stages to the out position and back again occupied a couple of hours, even in a calm sea.

Is it the conviction of the author that the pitot log, with its great inertia, gives accurate values of the speed ? The reason for this remark is the low figure of 5 per cent given for the added virtual mass. If account is taken of some inertia of the pitot log, the percentage will become somewhat higher, more nearly approaching the values given by previous experimenters.

Professor S. J. Palmer : From the point of view of one concerned with the teaching of the subject of resistance and propulsion of ships, the conclusions that appear to be of fundamental importance are that Froude's assumption that skin friction and wave-making should be regarded as independent is justified at least for the speed range (up to $V/\sqrt{L}=1\cdot0$) of the experiments, and that Froude's law of comparison for residuary resistance is shown to be accurate over this range.

Of great practical importance is the demonstration of the dependence of skin friction resistance on the smoothness of the wetted surface, and I might add that the maintenance of the smoothest possible surface is not less essential in warships than in merchant ships, since the former spend most of their time at sea at speeds at which the skin friction component predominates. It seems probable that the sensitivity of skin friction resistance to the condition of the surface makes it impossible to reach any firm conclusion on the determination of the best basic turbulent skin friction line. In fact, it may make us wonder why we give so much

thought to this question which is unlikely to affect ships' forms or alter estimates of speed and power, and yet pay comparatively little attention to obtaining really smooth hulls, which the trials have shown might yield very useful improvements in performance.

Mr. W. C. S. Wigley : I think there is a habit of giving too much importance to Lamb's curve. It is probably correct for a spheroid moving more than three or four diameters below the surface in a perfect fluid ; but if that same spheroid were floating in a perfect fluid the result would be to diminish that curve of virtual mass. If you are to compare with a theoretical curve these cases of floating bodies of ships it will be much better to use the rather nearer curve for the floating body in a perfect fluid. Nevertheless, the experiments discussed here do suggest to me that the actual virtual mass in a perfect fluid has probably very little effect comparatively. I think most of this apparent virtual mass must be due to disturbances of frictional flow.

My reasons are, first, that if the virtual mass were due in any way to perfect fluid considerations, it would almost certainly vary as the ship slowed down owing to change of wave-making. Secondly, the spots on the author's graph would be expected to be lower. Further, I believe that the fouling of the bottom did affect the virtual mass seriously. Taking that into consideration, this sort of pseudo virtual mass effect, must be due more to the frictional flow than to the perfect fluid flow which gives rise to the virtual mass of the text books.

Professor E. V. Telfer : Dr. Smith and his various colleagues have been very positive about this being the last of the " Lucy Ashton " papers. I can assure you it is not the last. They say that this paper concludes the presentation of the results ; but they may be encouraged to give more of the data they have taken.

I want to discuss chiefly the lesson we are trying to learn in connection with fouling. Professor Palmer suggested it was hardly necessary to have any precise use of friction lines. I should like to challenge that statement, because you can only get to know something precise about the fouling of ships if you have a precise friction line. If you use the Prandtl-Schlichting or Schoenherr line you get quite a different characteristic for roughness from that obtained if you use the Hughes line or my own line. So that the value of the paper is to join together the form of friction line and the form of the additive to smooth things up.

From that point of view, the paper is disappointing, because unfortunately and inevitably, the fouling is not pure. It is clear that there will be rust starting in the first place, and halfway through the experiment the sharp roughness of the barnacles comes in. So that the line you get is quite mixed in character, and I suggest that some of the conclusions are wrong. For example, I have for many years kept up a statistical analysis of the fouling of merchant ships which had been in service for long periods ; from that analysis, which now includes hundreds of ships, there is no possible doubt that the ordinary roughness in service, which does not include barnacles as such, but is merely the deterioration of the surface taking place between the ordinary dockings, does not take place uniformly with time. Early after dry docking it increases in rate and it slows down later.

The most satisfactory formula for statistical work appears to be that the loss in efficiency is proportional to the square root of the number of days out of dry dock ; at 100 days out of dry dock the loss of efficiency is, say, 10 per cent, and at twenty-five days the loss is already 5 per cent. Some interesting support of that type of variation is given in the paper by Dr. Allan and Mr. Canham, published last year. It is interesting that a small amount of barnacles can cause quite a lot of resistance.

Dr. J. F. Allan : Not the least important aspect of the work is that a lot more analytical work will be done, as Professor Telfer's remarks have indicated. Concerning basic friction lines, I agree with Professor Telfer but disagree with Professor Palmer. The really important point about the determination of the basic friction line is the question of what is the true roughness effect. The enormous increase of resistance due to fouling and the roughness which has developed on the " Lucy Ashton " is very important ; but it is equally important to keep the matter in true perspective and to remember that the ship was tied up to a buoy in the Gareloch at the time of year when fouling is likely to be very bad, and I do not think it should be accepted as a general guide to the increase in roughness to be expected on a ship in service.

If you analyse the velocity distribution in the boundary layer, $u/U=(y/\delta)^n$, you find that the increase in the " n " coefficient is of the same order in the " Lucy Ashton " as it is in the " Lubumbashi " (dealt with by Professor Aertssen in his paper on " Sea Trials on a 9500 D.W. Motor Cargo Liner.") That seems to confirm the roughness measurements in the two cases. The general roughness gives a similar change in the velocity distribution in the boundary layer. In spite of that, you have a big distribution in overall resistance.

Captain H. B. Ellison : I have been interested in the remarkable effect of a small amount of fouling, and I want to recall an experience in that connection. On the way home in H.M.S. " Belfast," I wanted to carry out certain consumption trials, and I left Hong Kong after six weeks in harbour, on the cruising turbines. but found that I could not reach my speed, and on arrival at Singapore I asked that the ship be dry-docked and cleaned, and in dry dock it was found that all over the bottom there was a good layer of barnacles, amounting in some cases to about ½in. It was suggested that she need not have dry-docked, and that my trouble was that the propellers were covered with barnacles and therefore were getting a lot of cavitation. However, the fact remained that, having cleaned the bottom, we could immediately reach our speed on the cruising turbines alone.

Professor S. J. Palmer : I wish to make it clear that I was not decrying the importance of attaining the reliable basic skin friction line ; I was not suggesting that it should be abandoned or was not of fundamental importance. I intended merely to remark that we have given it a great deal of attention during the last few years, and that perhaps we have not given the proportionate amount of attention to obtaining smooth hulls.

I do feel that there is a great deal we can do and a great deal of practical advantage that we can reap by going for flush welded hulls, paints which are smoother than those used in the past and anti-fouling compositions which are more effective.

(To be continued)

Side-operated Fork-lift Carrier

THE accompanying illustration shows a diesel-driven, hydraulically-operated carrier made by Albert Irion Nachf., Stuttgart-Münster, German Federal Republic. The vehicle, which measures 13ft 9in by 6ft overall, is intended for stacking, loading and unloading, and for the short-distance transport of bulky goods, such as timber, rails, pipes or packing cases. Its lifting fork is mounted on a telescopic mast which can be traversed across the machine. In this way, the fork can pick up or stack goods at any level from ground level to 10ft high and also transfer its load to and from the deck of the vehicle. At 20in load centres the maximum lifted is 6600 lb. When loads are being handled by the fork, the carrier must be stabilised by lowering the two hydraulic jacks seen in the illustration.

The side operation of the lifting mechanism is of great help in confined spaces, and the width of gangways need not be much in excess of the width of the carrier. A narrow turning circle of 9ft inner diameter makes manœuvring easy.

The vehicle is of welded construction, and has an unladen weight of 10,080 lb. It is powered by a Mercedes-Benz OM.636, four-cylinder diesel engine, which develops 30 h.p. at 2500 r.p.m. The drive is through a single-plate dry clutch and crash gearbox to the rear wheels. Five forward speeds and one reverse give speeds in the range 2·5 m.p.h. to 15·5 m.p.h. A centre-pivoted steering axle enables the carrier to accommodate itself to rough ground. The hydraulic system comprises a Plessey 6·6 g.p.m. gear pump coupled to the gearbox, and also the operating cylinders for mast, fork and jacks. Each movement is controlled from the cabin by an individual lever, with warning lights to indicate when the jacks are down. Overloading is prevented by a relief valve which is set to 2275 lb per square inch.

Carrier with mast in sidemost position and fork fully raised. Stabilising jacks are lowered to balance the load

B.S.R.A. Resistance Experiments on the "Lucy Ashton"*

MISCELLANEOUS INVESTIGATIONS AND GENERAL APPRAISAL

By S. LIVINGSTON SMITH, C.B.E., D.Sc.(Eng.).†

This is the fourth and final paper dealing with the presentation of the results of the experiments carried out on the "Lucy Ashton" by the British Shipbuilding Research Association. It is concerned with certain miscellaneous investigations, which included (a) the effects of fouling on resistance corresponding to various periods of immersion at different times of the year; (b) acceleration and retardation trials from which the virtual mass of the ship was determined; (c) pitot traverses in the ship's frictional belt, giving velocity distributions for various hull surface conditions. A general appraisal is given at the end of the paper in which the principal findings from the work as a whole are briefly reviewed. Arising from this, some suggestions are made regarding the general lines on which further work might be pursued.

THE previous papers covered the main part of the programme and dealt with the details of the experimental equipment[1] the ship-model correlation for the naked hull conditions,[2] and the ship-model correlation for the shaft-appendage conditions.[3]

The original programme of tests also provided for resistance trials in the fouled condition and acceleration and retardation trials as opportunity offered, but these were regarded as secondary in importance to the rest of the programme. Owing to rather fortuitous circumstances it so happened that both sets of trials were successfully and conveniently combined and carried out together. The object of the acceleration and retardation trials was the determination of the virtual mass of the ship which, in conjunction with other data, could be used in the calculation of the acceleration and retardation of other ships. Results are also given of pitot traverses made in the ship's frictional belt.

General.—The resistance tests carried out on March 28 to 30, 1951, in the clean naked hull condition with faired seams and aluminium paint concluded the main part of the programme, and the ship was then docked for inspection on April 5th. This showed that the hull surface was still in good condition, and the ship was refloated on April 7th with a view to carrying out acceleration and retardation trials in this condition.

The opportunity did not arise until the vessel had been out of dock for twenty-four days. In view of possible deterioration of the hull surface, it was considered necessary to check the resistance at the same time as the acceleration trials were carried out. The ship was started from rest and the acceleration was measured over the whole of the approach run. A normal pair of runs was then made at the constant terminal speed and, at the end of the return run, i.e. when the southern mile posts were reached, the engines were stopped and the ship lost speed under the action of her own resistance. During this part of the test, the course was maintained and the retardation measured. Pairs of runs were made in this manner at terminal speeds of about 12 knots and 14½ knots, and it was found that the resistance had in fact increased by 7½ per cent and 5 per cent respectively, as compared with the clean ship tests. This was ascribed to the onset of fouling or other deterioration of the bottom. The acceleration and retardation results would, of course, be of limited value without the corresponding resistance curve over the whole speed range, and it was decided that more runs should be made to define the new curve. Unfortunately, it was not practicable to carry out the necessary runs until six days later.

On May 7th, therefore, several pairs of resistance runs covering the whole speed range were carried out, and it was apparent that a further increase in resistance had taken place. As compared with the clean ship condition, the increase in resistance was almost twice that measured six days previously (i.e. about 14 per cent at 12 knots), and showed that the bottom was fouling or deteriorating at a rapidly increasing rate.

In view of the rapid increase of resistance, immediate docking of the ship was very desirable in order to examine the state of the bottom. Unfortunately, it was not possible to do this until June 6th, and the opportunity was taken on June 4th to make several runs over the speed range with the object of ascertaining whether any further increase in resistance had taken place. The increase at 12 knots was as much as 30 per cent, which was more than twice that measured on the previous occasion twenty-eight days earlier.

Resistance Tests in the Fouled Conditions.—The fouling took place on a bituminous aluminium paint surface which had no special anti-fouling properties and the vessel lay in salt water which varied in temperature from 43 deg. Fah. at the beginning of the fouling period (April 7, 1951) to 60 deg. Fah. at the end (June 4, 1951).

For purposes of comparison, the experimental results were again reduced to the same standard condition in the manner described in a previous paper.[2] This reduction of results included the following :—Correction to a standard water temperature of 59 deg. Fah.; elimination of wind and air resistance so as to obtain the water resistance only; elimination of tide effects on speed measurement; correction of resistance to a standard mean displacement of 390 tons; correction of resistance for the effects of rudder used during the mile runs.

From Fig. 1 it is apparent that there are not sufficient results to define completely a curve for each fouled condition, but it was found that the observations aligned themselves fairly well about curves obtained by adding to the clean ship resistance a constant percentage of the estimated skin friction resistance. The best justification for this is to be seen in the intermediate condition for thirty days out of dock, where most observations are available. These percentage increases have been calculated on two bases, namely, Froude and Schoenherr. As there is relatively little variation in the skin friction coefficients over the speed range, the increases in resistance can also be approximated by constant intercepts in resistance coefficient, which are commonly referred to as ΔC_f.

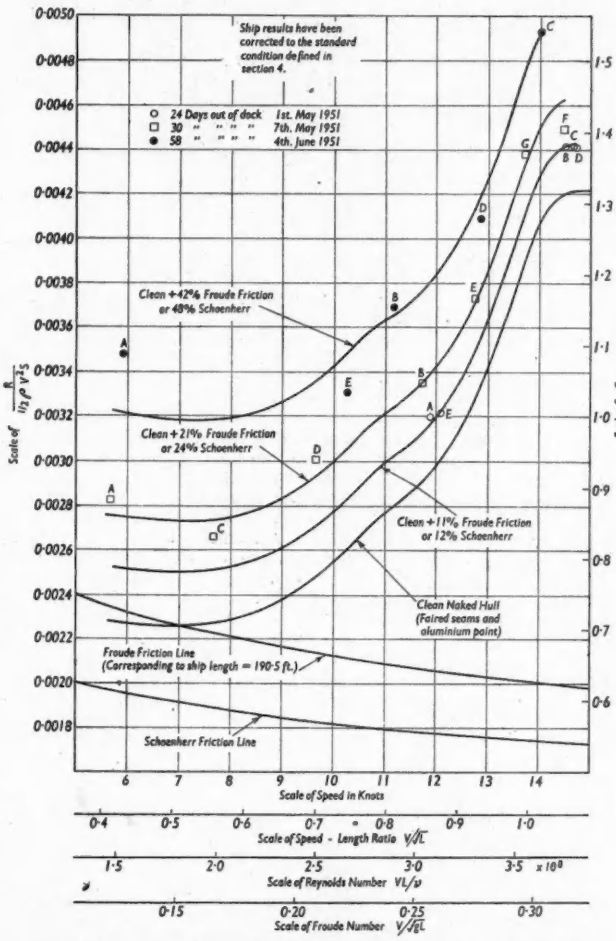

Ship results have been corrected to the standard condition defined in section 4.
24 Days out of dock 1st. May 1951
30 " " " 7th. May 1951
58 " " " 4th. June 1951
Clean +42% Froude Friction or 48% Schoenherr
Clean +21% Froude Friction or 24% Schoenherr
Clean +11% Froude Friction or 12% Schoenherr
Clean Naked Hull (Faired seams and aluminium paint)
Froude Friction Line (Corresponding to ship length = 190·5 ft.)
Schoenherr Friction Line
Scale of Speed in Knots
Scale of Speed - Length Ratio V/√L
Scale of Reynolds Number VL/ν
Scale of Froude Number V/√gL
Scale of C

Fig. 1—Comparison of full-scale resistance coefficients : naked hull, clean and after various periods out of dock

The individual observations show a fair scatter relative to the mean curve for the condition corresponding to fifty-eight days out of dock. It will be noted, however, from the group letters alongside the observations that, for this condition, there was a general tendency for the resistance to become progressively lower relative to the mean line as the trial proceeded, which would suggest that some of the fouling was being progressively washed off or at least smoothed in some manner. On the other hand, it is of interest to note that the observations for the first period (twenty-four days out of dock) show very good reproducibility.

A diagram shows the Nikuradse scale of sand roughness in conjunction with the Prandtl-Schlichting line for the skin friction of smooth surfaces. On this diagram, roughness allowances‡ have been set up above the smooth friction line to give curves of ship frictional coefficients for the various hull surface conditions. The character of the curves of ship frictional coefficients does not appear to bear any significant relation to that of the sand-roughness curves. Nevertheless, it has been possible to assign approximate average equivalent sand roughnesses for the different surface conditions, and the values are summarised in the following table :—

Basic hull surface. Faired seams with aluminium paint	l/k_s	k_s(in)
Clean	1×10^5	0·0023
Twenty-four days out of dock	5×10^5	0·0046
Thirty days out of dock	$3 \cdot 3 \times 10^5$	0·0070
Fifty-eight days out of dock	$1 \cdot 7 \times 10^5$	0·0135

where l = length of surface = ship length = 190·5ft.
k_s = diameter of equivalent sand grain.

Fig. 2 shows the percentage increase in skin friction on both the Froude and Schoenherr bases.

Nomenclature and Symbols

C—Resistance coefficient $= \frac{R}{\frac{1}{2}\rho V^2 S}$.
C_f—Frictional-resistance coefficient $= \frac{R_f}{\frac{1}{2}\rho V^2 S}$.
ΔC_f—Increment in frictional resistance coefficient.
ehp—Effective horsepower.
F_n—Froude number $= \frac{V}{\sqrt{gL}}$.
FP—Forward perpendicular.
g—Acceleration due to gravity.
k—Added virtual mass coefficient.
L—Length of ship (LBP).
R—Resistance in general.
R_f—Frictional resistance.
R_n—Reynolds number $= \frac{VL}{\nu}$.
S—Wetted surface area.
$t°$—Temperature of water.
V—Speed.
Δ—Displacement.
∇—Volume of displacement.
ν—Coefficient of kinematic viscosity.
ρ—Specific density (mass per unit volume.)

* Institution of Naval Architects, Spring Meeting. Abstract.
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‡ These roughness allowances correspond to correlation on the Prandtl-Schlichting basis which is the background, as it were, of the Nikuradse scale of sand roughness. As explained in Reference 3, these allowances are almost identical with those obtained on the Schoenherr basis.

Results are available only at four positions; the curves drawn must therefore be regarded as speculative especially between nil and twenty-four days out. With regard to this region interpretations suggest that the fouling became resistance sensitive after about eighteen days, or after about twelve days out.

After fifty-eight days out, the increase in total resistance amounts to 42 per cent at 6 knots,

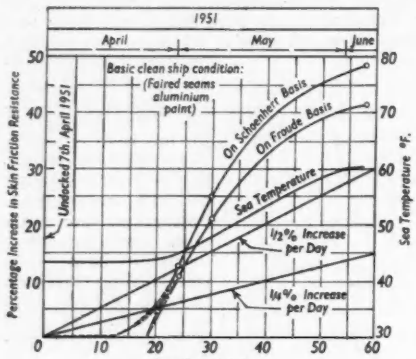

Fig. 2—Effect of days out of dock on estimated skin-friction resistance

29 per cent at 12 knots (the service speed), and 21 per cent at 14 knots.

Regarding the linear rates of increase in skin friction of ¼ per cent and ½ per cent per day out of dock shown in Fig. 2, these were quoted by Gawn[4] for temperate and warm waters respectively, and were averaged results based on trials carried out by the Admiralty before the last war. (It is understood that Admiralty experience with post-war bottom compositions and treatments is that the above figures should be roughly halved.) These average rates of increase appear to over-estimate the effect up to about twenty days out and under-estimate beyond that time. The over-estimate up to twenty days out is doubtless due to linear averaging, whereas the reason why the average daily rates for both temperate and warm waters are less than that actually measured over the total period of fifty-eight days is doubtless that the Admiralty vessels were under service conditions and were treated with anti-fouling compositions. One of the qualitative findings from the present work is that for the particular conditions described the daily rate of increase of skin friction was not linear.

The ship was slipped two days after the last trial in the fouled condition which took place fifty-eight days after the previous undocking. The inspection showed that the state of the bottom was not nearly so bad as had been expected. Apart from a few relatively small isolated patches, the basic aluminium paint surface was generally intact. The fouling consisted of two distinct kinds, namely:

A band of fine grass-like weed along the length of the ship, extending from the waterline down the ship's side. For about 60 per cent of the length amidships, this band was approximately 4ft wide and extended down to the turn of bilge. At the ends of the ship it tapered to a width of about 3ft.

Below the grass band there was no vegetable growth, but the whole area was covered with small white conical shells. On the average, they were about ⅛in high and $\frac{3}{16}$in diameter at the base, about thirty to thirty-five per square foot.

These fouling trials have shown the sensitivity of full-scale ship resistance to small roughnesses. A general but light scattering of small barnacles on the flat of bottom in association with a band of fine grasses on the sides gave rise to increases in the measured resistance of 42 per cent, 29 per cent and 21 per cent at speeds of 6, 12 and 14 knots respectively. This corresponds to an increase in the estimated skin frictional resistance of the order of 50 per cent.

The above gross increases in resistance due to fouling correspond to a lying-up period of fifty-eight days at a buoy in the spring and summer. Measurements of resistance suggest that there was probably no measurable increase in resistance before about twelve days out, but the resistance certainly began to increase rapidly after the eighteenth day. The most rapid increase occurred between twenty-four and thirty days out, when the rate of increase in skin-frictional resistance amounted to about 2 per cent per day. After thirty days out, this rate of increase fell off somewhat, the average value between thirty and fifty-eight days being just under 1 per cent per day.

After the ship had been laid up at the same buoy for a period of forty days from December 21, 1950, the increase in resistance was found to be of the order of 3½ per cent, corresponding to about 5 per cent on the skin friction. Subsequent docking showed that there was no evidence of fouling apart from a thin coat of slime, and the increase in resistance was ascribed to this and to the deterioration of the paint surface. The corresponding figures for forty days out of dock for the later spring and summer trials would be 23 and 33 per cent respectively—nearly seven times as much. It is apparent therefore that a primary consideration in the development of fouling is the time of year, sea temperature, solar radiation, and the biological life cycle.

It is important to bear in mind that, in relation to the time out of dock, the measured increases in resistance apply only to the particular time of year and locality and also to the ship when laid up at a buoy and not under service conditions. It should also be remembered that the aluminium paint surface had no special anti-fouling properties. The most important consideration would appear to be the state of the bottom as determined on docking at the end of the fouling period and its relation to the increase in resistance measured immediately beforehand.

It has been shown that the measured increases in resistance due to fouling correspond approximately to constant percentages of the estimated skin frictional resistance for the clean hull, or, alternatively, to constant intercepts in resistance coefficient (ΔC_f). Curves of roughness allowances deduced from the ship-model correlation do not appear to bear any significant relation to Nikuradse's curves for sand roughness resistance.

The previous trials in the clean naked hull conditions gave proof of the sensitivity of resistance to hull surface conditions, and demonstrated the importance of obtaining the smoothest practicable hull surface on ships. The gross increases in resistance measured on these later trials show how vitally important it is from the economic point of view to maintain the hull surface and keep it free from marine growths. This will be especially so for relatively low-speed ships where the skin frictional resistance forms an even greater proportion of the total resistance.

Acceleration and Retardation Trials.—Two sets of acceleration and retardation trials were carried out. On the first occasion, the ship had been out of dock for twenty-four days, and subsequent analysis showed that the resistance had increased slightly owing to the onset of fouling. The primary object of the trials on the second occasion was to define the resistance curve for use in conjunction with the analysis of the previous acceleration trials. It became apparent, however, that a further increase in resistance had taken place owing to progressive fouling, and several acceleration runs were therefore carried out to correspond to the changed resistance.

The following trials procedure was generally adopted. The ship was manœuvred into a stationary position about 1 mile south of the southernmost mile post in the Gareloch, and the engines were then set full ahead as quickly as possible. The ship was then accelerated on the approach to the mile, after which a normal pair of runs was made over the measured course. When the southern mile posts were again reached the engines were cut to idling and the ship was retarded under the action of her own resistance.

Continuous records were taken of water speed, wind speed and direction, rudder angles and engine thrust. In order to determine the acceleration and retardation, it was essential to have direct and continuous measurement of water speed, and two methods were used, namely, pitometer log and floating drogue. The determination of acceleration involved double differentiation of the latter, but only simple differentiation of the former. For these reasons, the pitometer-log records were considered the more reliable, and attention was confined to these in the analysis.

The principal outcome of these trials was the determination of the virtual mass of the ship, which, in conjunction with other data, could be used in acceleration and retardation calculations for other ships.

On the first occasion five complete manœuvres were made, namely, two with a nominal terminal speed of 12 knots and three at a nominal speed of 14½ knots. Fig. 3 shows a presentation of the results for an acceleration to 12 knots.

Referring to Fig. 3, the experimental observations are shown in conjunction with the curves of ship speed, engine thrust, and wind resistance. The remaining curves without observations have been deduced from these. The relative wind

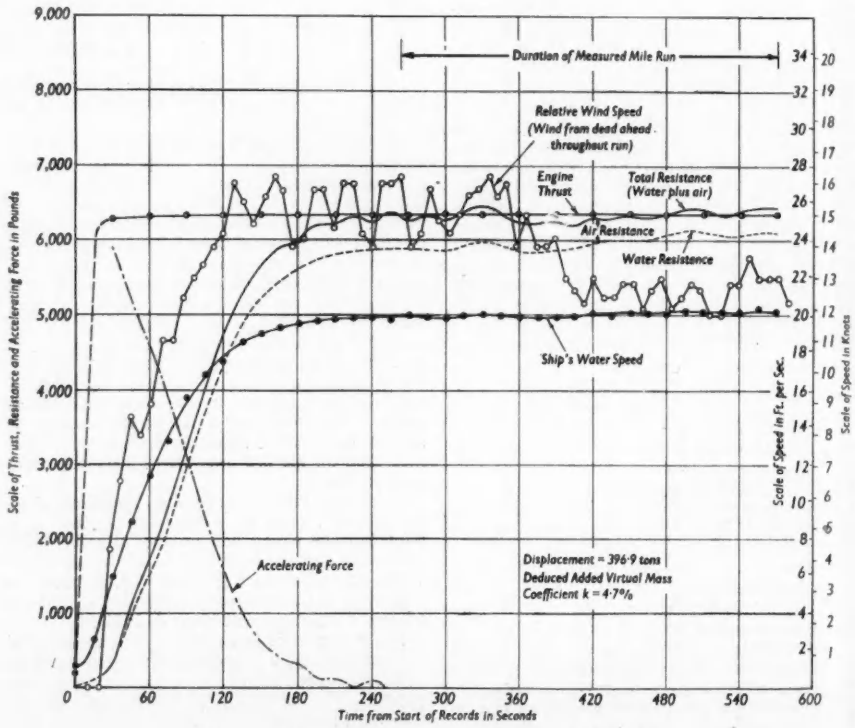
Duration of Measured Mile Run
Relative Wind Speed (Wind from dead ahead throughout run)
Engine Thrust
Total Resistance (Water plus air)
Air Resistance
Water Resistance
Ship's Water Speed
Accelerating Force
Displacement = 396·9 tons
Deduced Added Virtual Mass Coefficient k = 4·7%
Scale of Thrust, Resistance and Accelerating Force in Pounds
Scale of Speed in Ft. per Sec.
Scale of Speed in Knots
Time from Start of Records in Seconds

Fig. 3—Acceleration run No. 1, terminal speed 11·9 knots

speeds show curious cyclic variations, and in view of this the observations have been joined by straight lines instead of attempting to draw a faired curve. The water resistance corresponding to the measured ship speed was then taken from the resistance curve for the day. To this was added the calculated air resistance using the wind tunnel data (see reference 2) and the measured relative wind speed, thus giving the total ship resistance. This did not always agree precisely with the thrust curve at the full terminal speed—the deviation being generally between 1 and 2 per cent. This, of course, corresponds to the slight scatter of the observations on the resistance curve with respect to the mean line. In such instances, the resistance ordinates plotted in the acceleration and retardation diagrams were adjusted *pro rata* over the speed range, as an accurate balance between thrust and resistance at the terminal speed was essential to the analysis.

It will be noted that over the second half of the mile run there is a drop in the general level of the relative wind speed as compared with the first half, and this is reflected by a slight but noticeable increase in water speed. As the water speed was about 12 knots over the mile, it will be seen that the natural wind was about 3 knots over the first half and almost nil over the second half.

The "dynamic" mass or displacement was then calculated from the accelerating force and velocity curves and is expressed in terms of the "static" mass or displacement. The former is generally slightly greater than the latter owing to the water carried along by the ship as she accelerates. The relation between the two masses or displacements is expressed as follows :—

$$\frac{\text{dynamic displacement}}{\text{static displacement}} = 1 + k,$$

where k, generally expressed as a percentage, is usually known as the added virtual mass coefficient.

On the second occasion when such trials were carried out (May 7, 1951), two complete manœuvres were made, one at a nominal terminal speed of 13¾ knots and the other at 14¼ knots. The results of the analysis of both sets of trials are summarised in the following table :—

Run No.*	Direction†	Terminal speed, knots	Virtual mass coefficient k, per cent	Remarks
1A	N	11·9	4·7	
2R	S	11·9	4·8	
3A	N	14·6	5·4	First series run on May 1, 1951 (twenty-four days out of dock)
4R	S	14·5	Incomplete records	
5A	N	14·8	Incomplete records	
6R	S	14·6	4·3	
7A	N	14·8	—	
8R	S	14·6	3·2	
9A	N	12·2	6·2	
10R	S	12·0	1·3	
11A	N	14·5	4·8	Second series run on May 7, 1951 (thirty days out of dock)
12R	S	14·5	6·8	
13A	N	13·75	13·0	
14R	S	13·75	Incomplete records	

* A=Acceleration run R=Retardation run
† N=North S=South

Referring to the first series, it will be noted that there is appreciable variation in the k values, the range being from 1·3 to 6·2 per cent and the average value about 5 per cent. It has to be borne in mind that the determination of the dynamic mass involves the differentiation of an experimental curve, a process which is extremely sensitive to small errors, and, moreover, the final k factor is itself a small difference between the dynamic mass and the static mass (or displacement), which again tends to magnify errors. Nevertheless, it is considered that the weight of statistical evidence is in favour of a figure of 5 per cent for these experiments.

For the second series, only three values are available : two of these are of the same order of 5 per cent as determined for the first series, but the third is appreciably higher at 13 per cent. It is rather difficult to draw any definite conclusions from the second series alone, except perhaps to say that it does not indicate a value of k substantially different from that of the first series. This is interesting when it is remembered that in the second series the skin friction resistance had been increased by some 20 per cent owing to fouling and in the first series by 10 per cent for the same reason. The virtual mass does not appear therefore to be particularly sensitive to an increase in resistance of this order, and it seems reasonable to assume that the value of k for the clean ship would be substantially the same, namely, 5 per cent.

Pitot Traverses.—As explained in Reference 1, two pitot logs were fitted in the ship's hull close to the middle line : No. 1—72ft 6in, and No. 2—97ft 4in aft of the forward perpendicular.

The primary object of fitting these logs was to explore the velocity distribution in the boundary layer for the various hull-surface conditions in conjunction with the measured-mile runs. This work, however, was regarded as of secondary importance to resistance measurements. In the fully extended position, the logs were also used to measure the ship's water speed during the acceleration and retardation trials.

In making a pitot traverse, the procedure was generally to make a double run on the mile and to take readings while the log was traversed in stages to the out position and back again. It was generally possible to complete this on one leg of the mile and then repeat the process over the return run. The mean speed deduced from this double run on the mile was used to calibrate the log in the fully extended position.

Fig. 4 shows results for traverses taken with the No. 1 log in the clean naked-hull condition with sharp seams and red-oxide paint at three speeds, namely, 5·45 knots, 10·07 knots and 14·24 knots. The vertical scale is the distance out from the shell in inches, and the horizontal scale is the velocity in the boundary layer expressed as a fraction of the free-stream velocity.

There is a fair scatter of the observations, but when the mean curves are drawn it is just possible to distinguish a slight difference between the curves on the composite plotting for the three different speeds. The boundary-layer thickness at this position appears to be of the order of 12in.

The corresponding Reynolds numbers VL/ν and frictional-resistance coefficients C_f are also indicated. The latter have been obtained by integrating the loss of momentum in the boundary layer determined from the mean curves shown in the figure, and correspond to a surface whose length is equal to the distance of the log from the fore-end of the ship. This length was also used in calculating the Reynolds number.

Traverses taken with No. 2 log for the naked-hull condition with faired seams and aluminium paint, both clean and after fifty-eight days out of dock, show similar results. Both traverses are at about the same speed : 10·18 knots (clean) and 10·30 knots (fouled). The remarks made above again apply generally, but there is an appreciable difference between the velocity profiles for the clean and fouled conditions. It is apparent that the boundary layer at this position was of the order of 18in thick. This compares with 12in measured on the No. 1 log, which was situated some 25ft further forward. This is in accord with the increase in thickness of the frictional belt with distance from the fore end of the ship.

General Appraisal and Review of Principal Findings from the "Lucy Ashton" Investigations

The trials carried out in the clean naked-hull conditions have given proof of the sensitivity of full-scale ship resistance to small roughnesses. In particular, when referred to the normal clean service condition of the hull it has been shown that : fairing the seams reduced the total resistance by about 3 per cent ; painting the hull with the smoother bituminous aluminium paint instead of red-oxide reduced the total resistance by a further 3 per cent.

It is important to bear in mind that the above reductions in resistance are of much the same order and not less than improvements achieved due to changes of form as evinced by comparative tests on models. Further, the quality of the hull surface in the clean condition with sharp seams and red-oxide paint, was considered comparable with that of the freshly painted plates of a new ship. Experience shows, however, that in some ships the quality of hull surface may be inferior to this and it is not unknown for sister vessels on measured mile trials in the clean condition to show differences in power which are of the order of 15 per cent.

Resistance tests in the fouled conditions showed the sensitivity of full-scale ship resistance to small roughnesses. A general but light scattering of small barnacles on the flat of bottom, together with a band of fine grasses on the sides, gave rise to an increase in the measured resistance of almost 30 per cent at the service speed of 12 knots which corresponds to an increase in the estimated skin-friction of the order of 50 per cent. This refers to a lying-up period of fifty-eight days, in the Gareloch in the spring and summer, and to fouling on a paint surface which had no special anti-fouling properties.

The trials with the clean ship demonstrated the importance of obtaining the smoothest practicable hull surface, and those in the fouled conditions have shown how important it is from the economic point of view to maintain the surface and keep it free from marine growths.

When trip-wires were introduced as turbulence stimulators on ship models some years ago, doubt was expressed as to the effect which corresponding excrescences would have on a full-size ship. To throw some light on this, runs were made with a ¼in diameter "trip-wire" fitted to the ship which was comparable in size to the standard trip-wire fitted on the 12ft model. These tests showed that, for this particular form, the percentage effect on the full-scale resistance was of much the same order as the 1 to 2 per cent measured on the model, which was subject to little or no laminar flow.

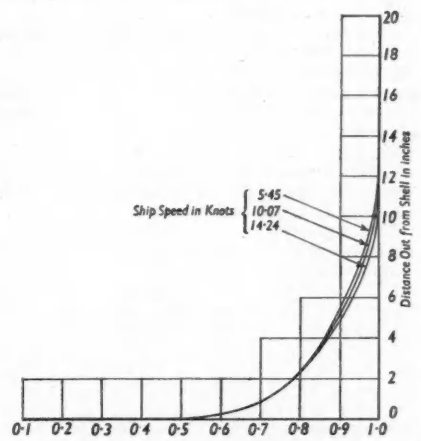

Fig. 4—Pitot traverses : hull surface with sharp seams and red-oxide paint (clean)

The added virtual mass of the ship determined from the acceleration and retardation trials has been correlated with the results of previous work, and, for the first time, a curve of added virtual mass coefficients has been developed covering a wide range of ship forms and streamlined bodies. This will be of use in acceleration and retardation calculations for other ships.

Frictional resistance coefficients for the ship have been deduced from velocity distributions measured in the ship's boundary layer in both the clean and fouled conditions. These coefficients are of the same order as the corresponding values determined from the ship-model correlation of resistance measurements and give confirmation of the experimental results.

The ship results have been correlated with the results of tests carried out in No. 1 tank N.P.L. on a series of geometrically similar models ranging in length from 9ft to 30ft. This correlation was effected using the usual Froude frictional coefficients and also some of the more well-known modern skin-friction formulations.

As far as the model results were concerned an unexpected difficulty was that the results for the larger models above 20ft long were affected by the boundaries of the experiment tank. An approximate correction was made for this.

In way of the service speed of 12 knots and for the usual model lengths of 16ft to 20ft predictions on the Froude basis were close to the measured full-scale resistance. At the lower speeds, however, the predictions tended to overestimate the resistance, the prediction generally being higher the shorter the model.

On the Schoenherr basis with the roughness

allowance normally in use§ for clean new ships the predictions were again close to the measured full-scale resistance. The predictions at low speeds again tended to be higher the smaller the model but to a lesser extent than on the Froude basis.

Of the modern Reynolds number-based formulations, although not entirely satisfactory, those due to Schoenherr and Prandtl-Schichtling appeared to be the most compatible in most respects as far as the correlation of the model results themselves was concerned and of these with the ship results. The compatibility of the different formulations depend to some extent on the magnitude of the corrections for tank boundaries on the results of the larger models. If it is eventually ascertained that this correction should be different to the approximation actually made, then some other formulation may prove to be the more compatible. This bringing into prominence of tank-boundary interference was one of the important side-lights of this investigation. Tests have shown that for the usual model lengths the boundary effects in the No. 1 tank at N.P.L. are negligible.

Although the investigation has not shown conclusively which is the appropriate skin-friction formulation for predicting ship resistance from model tests, it has enabled the performance of the various methods to be accurately assessed for a ship in the 200ft length category and for a wide range of model lengths. In addition to the accurate measurement of full-scale resistance in various conditions, comprehensive records of the corresponding hull roughness are also available.

The alignment of the cross-curves of constant Froude number on the extrapolation diagrams suggests that, as far as this family of geometrically similar models is concerned, Froude's law of comparison has been vindicated as regards the scaling-up of wave-making resistance in the usual manner. This can also be extended to include the measured ship resistance subject to the acceptance of the roughness allowances which, of course, depend on the particular skin-friction formulation used. This also implies that, within the range of these investigations, the interference between the skin-frictional resistance and wave-making resistance was negligibly small from the practical point of view. It is not suggested, however, that this will necessarily be so at higher speeds and Froude numbers.

§ The usual 0·0004 on C_f as recommended by the American Towing Tank Conference.

Tests with twin-screw shaft appendages showed that, to scale, the resistance increments on the ship were roughly half those measured on the models. The results for the bossings differed from some previous work confined to the model scale which showed no perceptible scale effect, but it is considered that this may be due to the fact that in that instance the bossing webs were aligned in the flow, whereas in the present investigation they were inclined across it. Subject to this reservation, current practices in the assessment of shaft-appendage resistance have been generally confirmed.

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Precast Concrete Structural Assemblies

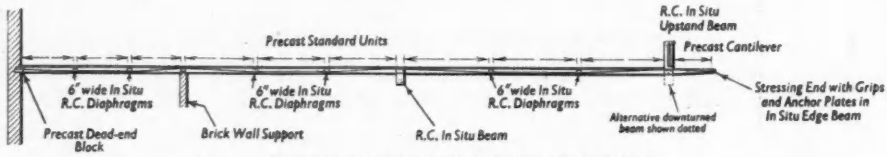
A NUMBER of firms specialising in concrete work have recently formed a company known as Raphcon, Ltd., of 2, Caxton Street, London, S.W.1 (the name is a contraction of "reinforced and prestressed hollow concrete units") to market precast concrete structural units. The "Raphcon" system is based on a hollow precast beam unit, made with a collapsible metal core, and the units may be combined in various ways to give spans up to 40ft or more, with three or five units extending over one span. The units are of various sizes in cross section (from 5in to 10in deep and 12in to 15in wide), to suit different ranges of load and span, and they may be for singly-supported applications, when pretensioned units are used, or for cases such as the one illustrated, where post-tensioned reinforced units are employed.

A typical recent use of the system—a factory at Foots Cray in Kent—is shown in the drawing. The area of the floor was 590 square yards, in this case, and the design load was 200 lb per square foot, plus 18 lb per square foot for finishes. Post-tensioned construction was used to form a continuous slab with bays of 16ft 4in, 11ft 6in and 16ft 4in.

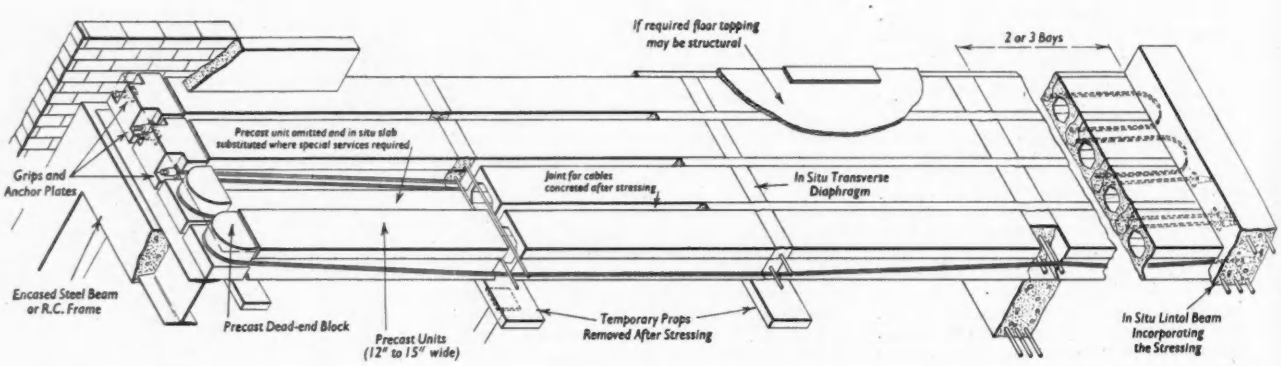
During construction, three or five short lengths of lightly reinforced units are arranged in line in each span, supported on temporary props, with 4in to 6in gaps left between their ends. Sets of longitudinal prestressing wires are next placed on each side of the units, and steel reinforcement placed across them—over the prestressing wires at the propped gap point, and under at the main supports. With a smaller central span, as in this particular example, the loading on the outside bays can cause a negative moment in the central span; therefore, some of the prestressing wires are arranged in both the top and bottom of the centre span, and all in the bottom only of the outside bays.

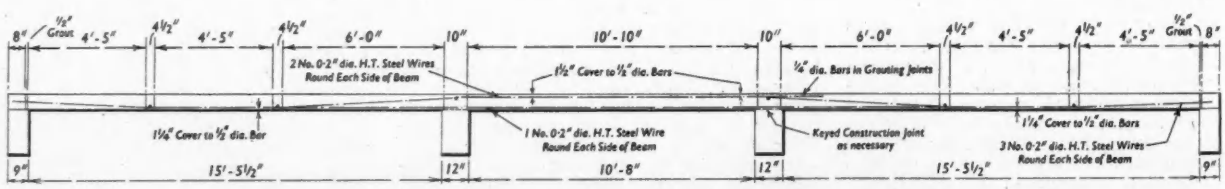
The gaps between unit ends are then concreted, to form a series of continuous beams. The floor is stressed by a jack, which acts by thrusting against a precast stressing block, concreted on to one end of the continuous beam, and pulling from a precast "dead-end" block at the other end. The beams are stressed from alternate ends.

After stressing the floor is fully suspended and continuous and may be tested, although concreting has not yet taken place between beams. The beams are finally concreted together. No topping or screeding is required structurally. The floor will behave as a monolithic slab over the three bays, we are informed, with about one-fifth of the deflection of a simply supported span, and the transverse reinforcements or diaphragms will distribute any point loads. The units for this floor were produced in six weeks and the floor itself was laid in a further two weeks.


R.C. In Situ Upstand Beam
Precast Standard Units
Precast Cantilever
6" wide In Situ R.C. Diaphragms
6" wide In Situ R.C. Diaphragms
6" wide In Situ R.C. Diaphragms
Stressing End with Grips and Anchor Plates in In Situ Edge Beam
Alternative downturned beam shown dotted
Precast Dead-end Block
Brick Wall Support
R.C. In Situ Beam

TYPICAL SECTION THROUGH SLAB SHOWING ALTERNATIVE TYPES OF SUPPORT.

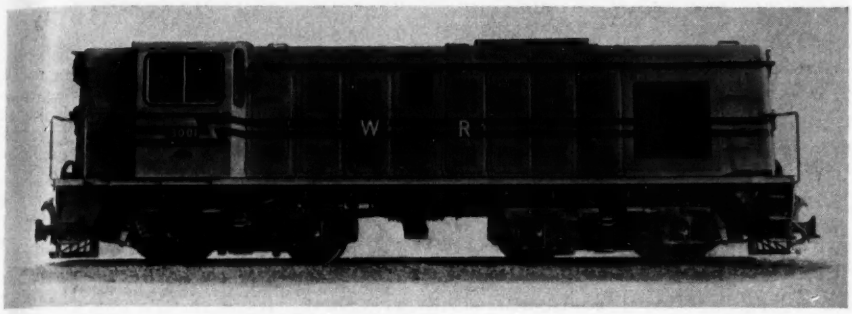

If required floor topping may be structural
2 or 3 Bays
Precast unit omitted and in situ slab substituted where special services required
Grips and Anchor Plates
Joint for cables concreted after stressing
In Situ Transverse Diaphragm
Encased Steel Beam or R.C. Frame
Precast Dead-end Block
Precast Units (12" to 15" wide)
Temporary Props Removed After Stressing
In Situ Lintol Beam Incorporating the Stressing


8" ½" Grout 4'-5" 4½" 4'-5" 4½" 6'-0" 10" 10'-10" 10" 6'-0" 4½" 4'-5" 4½" 4'-5" ½" Grout 8"
2 No. 0·2" dia. H.T. Steel Wires Round Each Side of Beam
1½" Cover to ½" dia. Bars
¼" dia. Bars in Grouting Joints
1¼" Cover to ½" dia. Bar
1 No. 0·2" dia. H.T. Steel Wire Round Each Side of Beam
Keyed Construction Joint as necessary
1¼" Cover to ½" dia. Bars
3 No. 0·2" dia. H.T. Steel Wires Round Each Side of Beam
9" 15'-5½" 12" 10'-8" 12" 15'-5½" 9"

Typical application of precast units using post-tensioning and continuous construction

625 H.P. Diesel-Hydraulic Locomotives

An illustration on this page shows one of twenty metre-gauge, "B-B" diesel-hydraulic locomotives which are now being completed at the works of the North British Locomotive Company, Ltd., Springburn, Glasgow. The locomotives are intended for service on the 170 miles long Kandla Deesa section of the Western Railway of India, which has a ruling gradient of 1 in 200 except for a section of about 1 mile outside Deesa, where the gradient is 1 in 150. Each locomotive is powered by a Paxman "12RPHXL" Series II, turbo-charged, twelve-cylinder vee engine with a twelve-hour rating of 625 b.h.p. at 1250 r.p.m. Drive to all four axles



625 h.p. diesel locomotive with "Voith-North British" hydraulic transmission. The locomotive weighs 43 tons and has a maximum tractive effort of 24,200 lb

of each bogie is through a "Voith-North-British" hydraulic transmission, cardan shafts and axle-mounted spiral bevel and spur wheel gearboxes.

The locomotives each weigh 43 tons and are designed for a maximum tractive effort of 24,200 lb, and a maximum speed of 55 m.p.h.

The main frames are welded from mild steel plates and sections. The buffer beams are riveted to the main frame and brackets and fittings which may have to be removed for dismantling and repairs are secured with fitted bolts.

The cab and engine housing are built of mild steel plates, pressed steel doors being fitted in the engine housing sides and roof to give access to the engine and auxiliaries. The cab is entered by doors opening on to the platforms on either side of a short housing containing the batteries and control air reservoir. The 600-gallon capacity fuel tank separates the cab from the centrally placed compartment containing the engines, transmission, compressor and exhausters. Air intakes to the engine turbo-blowers are separately ducted through Vokes panel filters, which are accessibly mounted on the side walls of the housing, drawing cool air direct from the outside.

Beyond the engine compartment is the radiator housing with side-mounted cooling panels, the air being drawn through the panels by a vertically mounted, engine-driven fan, and expelled through the roof of the housing. The fan is driven from the free end of the engine through a bevel gearbox and Layrub shaft with a centrifugal coupling to take the drive smoothly.

In the all-welded bogie frame, each side frame is made from two steel pressings welded longitudinally together to form a box section. These frames are joined by a cross stretcher built from plates and welded in place. Tractive, braking and transverse forces are taken by a cast steel pivot pin with a hardened steel spherical bush working with grease lubricated socket, arranged low down in the bogie stretcher. The weight is carried on a central pivot of large diameter, with side steady bearers at a nominal clearance to check roll.

The bogie frames are supported by a single large laminated spring on each side suspended by links from equalising beams resting on top of the axleboxes. The axleboxes are fitted with grease lubricated Skefko roller bearings and there are manganese steel liners on axlebox and horn guide faces with provision for oil lubrication.

The engine is flexibly supported at four points on rubber mountings in shear, and vibration is damped to a minimum. It is connected to the hydraulic transmission by two "Holset" flexible couplings with a short spacer shaft between them. The exhaust manifolds connect with the two turbine inlet ports, the outlets being ducted through the roof at the rear of the engine housing. The hydraulic governor is driven from the free end of the camshaft through bevel gearing. An electro-pneumatic remote control gear gives seven speed steps from idling to full load.

The lubrication system of the engine is primed by a gear oil pump driven by an electric motor which cuts out when the engine fires, and it provides oil to all bearing surfaces and the hydraulic governor. When the oil pressure has reached a safe value an oil pressure switch closes and operates the starter motor contactor.

The "Voith-North British" type "L36r" hydraulic transmission contains three torque converters. Infinitely variable torque multiplication is inherent in the design of each hydraulic torque converter, but one is designed to be most efficient at starting and low speeds, the next for intermediate speeds and the third for high speeds. The converter which is most efficient in the prevailing conditions of speed and load is automatically selected by the hydraulic control gear inside the transmission without any attention from the driver. The converters not in use are automatically emptied of oil, and one converter is filled as another is emptied so that the change is made without interruption in the transmission of torque to the wheels.

The transmission oil is cooled by a heat exchanger where the heat is transferred to the engine cooling water system. This method ensures rapid warming-up to the best operating temperature and prevents excessive temperature rise even under severe overloads.

Reverse gears are built in to the output side of the transmission and the direction is changed by air cylinders. The gears remain locked in mesh even if air and electricity supply should fail.

The drive from the hydraulic transmission to the primary and secondary axle-mounted gearboxes is through Hardy Spicer cardan shafts. The primary gearbox on each bogie transmits the torque through single helical and spiral bevel reduction gears to the inner axle of each bogie, and from each bevel gear shaft a secondary cardan shaft drives the secondary gearbox on the outer axle. This gearbox has spiral bevel reduction gears similar to those on the primary gearbox. Reaction torque from each final drive gear is taken through torque arms and rubber bushes to the main cross stretcher of the bogie.

A Westinghouse system of vacuum controlled straight air brake is fitted and the driver's vacuum brake valve applies the train brakes and makes a proportional application of the locomotive air brakes. The air brake handle does not affect the train but makes a straight air application on the locomotive or on both locomotives if working in multiple.

Controls

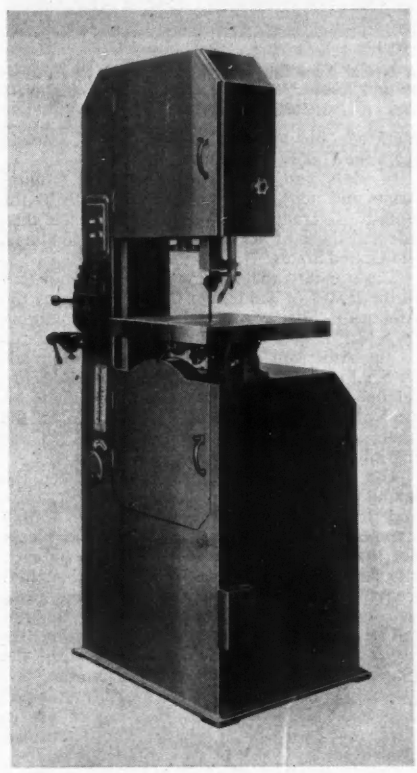
The control desk is arranged for driving in either direction, and the throttle, reversing, air brake and vacuum brake handles are duplicated on both sides. At the first notch on the throttle the engine idles but no power is transmitted because the oil supply to the transmission is cut off. At the next notch the transmission fills. The remaining notches give progressively greater engine speeds and greater power to the wheels up to the maximum.

The gauges, instruments, light switches and warning lights are all grouped on an instrument panel above the driver's desk and the Hasler speedometer with speed recorder is mounted to the left of this panel. Separate start switches allow either engine to be cut in or cut out at will when running the locomotives in multiple.

Band Sawing and Filing Machine

A band sawing and filing machine for work up to 8in thick now being made by the Midland Saw and Tool Company, Ltd., Pope Street, Birmingham, is illustrated below. It has a fabricated sheet steel body in which the top and bottom wheels are enclosed behind large flush-fitting doors. The 18in square table can be tilted up to 45 deg. on one side, 15 deg. on the opposite side, and up to 15 deg. towards the front or rear.

Two saw guides with means of horizontal adjustment are fitted one above and one below the table, and the top guide can be adjusted vertically in accordance with the height of the workpiece. A removable carbide thrust pad and four pairs of hardened steel side pads are provided for each guide, these guides being suitable for use with saws up to ½in wide. A flush-mounted brazer on the front of the machine has a panel fitted with a clamp for holding a saw while the joint is being finished. If required, an electric butt welder can be supplied for welding and annealing saws up to ⅝in wide.



Band sawing and filing machine with four-way inclinable table and band speeds from 60ft to 500ft per minute

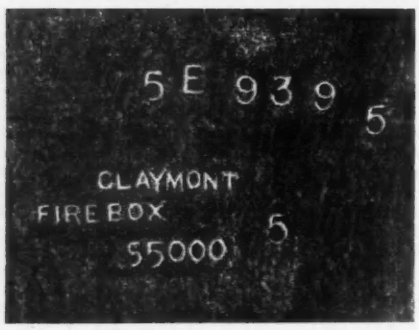
The machine is driven by an electric motor through a double variable-pitch vee rope pulley and a gearbox giving a range of speeds from 60ft to 500ft per minute. Speed variation is effected through a handwheel with reference to an indicator at the side of the machine.

For band filing the saw is replaced by an endless steel band fitted with twenty-six files and a special recessed jointing file. The file sections are automatically aligned on the band itself by locating pins. These filing bands are made in three widths of ¼in, ⅜in and ½in. If required, a pedal-actuated automatic work-feeding device can be fitted.

British Steel Plate in North America

BY OUR CANADIAN CORRESPONDENT

DURING the years there has been a major change in the requirements of the Provincial boiler inspection departments. Regulations that a few years ago were accepted as routine are now obsolete, with the result that equipment and material based on these old regulations do not meet the requirements of the inspection departments, and are subsequently rejected, or placed on a restricted usage. Of material most used in the engineering field, steel plate takes a prime importance, both in quantity used, and, unfortunately, in the multiple occurence of incorrect



A typical American stamping. Rubbing of markings on a "firebox" quality plate, showing satisfactory markings of American mills

markings on material imported into Canada from the United Kingdom.

In years past, the standard of plate requirements and markings were those set forth by the Board of Trade, but Canada has since then adopted those of her nearest national neighbour, the United States.

The standard that is now accepted is not that of the Board of Trade, but that laid forth by the American Society of Mechanical Engineers (A.S.M.E.), and the almost identical standards of the American Society for Testing Materials (A.S.T.M.).[1] The codes of these two Societies set out the minimum markings to be made on steel plate, the position of the markings on the plate, and the legibility of the markings. These markings are as follows :—

The name or brand of the manufacturer, the manufacturer's test identification number, class and lowest tensile strength shall be legibly stamped on each finished plate, in two places not less than 12in from the edges and on each butt-strap near the centre line not less than 12in from each end. Plates, the maximum lengthwise and crosswise dimensions of which do not exceed 48in, shall have the marking stamped in one place approximately midway between the centre and an edge. The manufacturer's test identification number shall be legibly stamped on each specimen. For plates under ¼in in thickness, the markings shall be legibly stencilled instead of stamped.[2]

This is the standard accepted by the inspection authorities, and it must be followed by the inspectors of imported plate. The Board of Trade standard is no longer the recognised standard in the Dominion for the chemical and oil refining industries. Generally speaking, it is now used almost exclusively for marine standards, but marine standards are not the accepted standards in the Dominion for stationary, locomotive, nor industrial pressure vessels. It is not that inspection authorities necessarily reject the former standard, but the customer and the engineering departments concerned, are not satisfied unless the standard meets implicitly the requirements of the A.S.M.E. Code.

It is a common occurence for United Kingdom mills to take orders for SA-285 standard plate. Yet, when the mill sheet comes out, the United Kingdom style specification sheets are still used and, moreover, all references are to British standards, not to the required A.S.M.E. or A.S.T.M. Standards. Accordingly, the stampings are not as laid out in the illustration.

The North American specification sheets vary to some extent, but they all list the pertinent facts concerning the steel, the chemical readings and the A.S.M.E. code standards. They contain the following essential material presented in a concise and methodical manner, and are immediately referable to each plate.

(*a*) All particulars relative to the SA-825 standard, listing at the head of the sheet all materials and chemical requirements laid down by the A.S.M.E. or A.S.T.M. Codes.

(*b*) The material and chemical analysis of each plate.

(*c*) Reference to the markings on the plate.

The procedure of inspection includes :

(*a*) A check on the thickness and quality of plate, a check for defects, and an examination of the mill sheet data for the plate.

(*b*) A check for the markings, which must be in accordance with the A.S.M.E. and A.S.T.M. Codes.

(*c*) A check of the actual tensile strength against the minimum tensile strength, which must be stated on the specification sheet and included amongst the plate stampings.

The Canadian and American specification sheets always state this minimum, which is essential for the customer, and a service to him and to the inspectors. Unfortunately, such sheets from the United Kingdom often do not show the minimum of the A.S.M.E. standard, nor, in some cases, do they include chemical and physical specifications on the sheet.

A mention of procedure that should be followed in stamping plates for the American and Canadian market will give an idea of the simple, yet almost universally omitted, markings that must be located before a plate is accepted as suitable for use on pressure vessels.

(1) Stampings must be positioned as stated in the aforementioned code, i.e. 12in in from the edges, and at both ends of plate. They must be on correct line, and legible.

(2) Name of manufacturer, brand, mill, legibly stamped.

(3) Minimum tensile strength for the grade (not of the plate itself) must be stamped.

(4) Grade or plate, i.e. flange quality or firebox quality must be used.

The U.K. term, "boiler quality," means nothing to the North American customer, and is accordingly, when used, apt to cause annoyance in the engineering departments.

Amongst criticisms made of British markings are :

(1) The majority of the markings are not legible ; they are hardly ever in the correct position, or in a straight line, sometimes one end only, and sometimes even in the middle of the plate.

(2) The name of manufacture is sometimes absent, or completely illegible.

(3) The minimum tensile strength is rarely stamped.

(4) The stamping "firebox" or "flange" quality is hardly ever to be seen.

Despite the fact that many of the inspectors give every consideration to the British manufacturers, there has recently been a case where a complete shipment of plate was rejected because of failure to fulfil requirements, or mark the plates correctly. The customer was left with no alternative but to have the material re-tested, or use it for secondary work not covered by the Inspection Acts.

There is no complaint as to the quality of material, and the inspectors concerned are agitating for the simple reason that they wish to improve conditions for British plate exporters by seeing that they meet the Code's standards. The opinion is expressed that nearly 100 per cent of the plates arriving from the United Kingdom are not suitably marked. It is obvious that where many of the inspectors are born and trained in the United Kingdom, they will give every encouragement to British manufacturers, but they have to meet the requirements laid down by A.S.M.E. and A.S.T.M., and where such an almost universal failure to comply is present, they necessarily find themselves rejecting more and more of the plate from the British Isles.

The accompanying illustration represents a rubbing of an American or Canadian marking, and the table shows a typical "mill sheet."

REFERENCES

[1] "Material Specification" section II, A.S.M.E. Boiler Construction Code, 1949 (1952), Foreword.
[2] "Material Specification," SA-285, Section 13, Marking, page 443, 1949.

Travers Irrigation Dam, Alberta

IN the year 1909 there was begun in southern Alberta an irrigation system covering an area which to-day is occupied by the Bow River irrigation project. This project extends from Carseland to Medicine Hat, which lies approximately 140 miles to the south-east, utilising the waters of the Bow River, and supplying some 240,000 acres in southern Alberta. The project originally used English capital in its development, when a group of companies inaugurated the system ; it was later taken over by the Canada Land and Irrigation Company and was subsequently purchased by the Government of Canada in 1950. At the time of this last transaction the irrigation company was serving 54,000 acres, and since the purchase the Canadian Government has been carrying out a programme of renovation and enlargement.

A Typical Mill Sheet Used by North American Mills

CERTIFIED REPORT OF CHEMICAL ANALYSIS AND/OR PHYSICAL PROPERTIES

CUSTOMER .....

ADDRESS .....

SHEET .....

DATE .....

Customer	Heat No.	Slab No.	Section	Yield point lb per sq in	Tensile strength lb per sq in.	Per cent elong. in	Per cent red in area	Bend test	Homo. test	C	MN	P	S	Cu	Location	Remarks
Spec. and requirements			A.S.T.M. A285-49 Gr. C		55/65000			180 deg.			0·80 max.	0·04 max.	0·05 max.	0·35 max.	—	—
(Example) 131	2B41	67	Flange qual. ⅜in × 72in × 234in	41020	64240	25·4	—	OK		0·18	0·39	0·01	0·04	0·17		
															Certified..... Chief Inspector.	

The completed system will include a weir and head gates on the Bow River, near Carseland, at the head of the system, impounding works for the Lake McGregor reservoir, the Little Bow dam and the recently completed Travers dam. Besides these works there will be balancing reservoirs throughout the project, connected by 115 miles of main canal, of capacity from 820 cusecs to 2700 cusecs. Five separate wood-stave siphons have been installed where the overtopping the contractor was forced to carry to completion the semi-pervious up-stream section well ahead of the schedule of construction. It was not until July that the inflow rate dropped to something near normal, and enabled construction to be carried on uninfluenced by the reservoir rise.

The cut for the spillway was commenced in the autumn of 1952, forms being erected, reinforcements laid, and concrete poured in the same year, the spillway being completed in April, 1954. The earth fill was completed at the same time, but work on the rip-rapping was carried on for some time after this. The outlet structure was completed in July, 1954, in time for the formal opening of the dam in the same month. The dam forms a reservoir, 12 miles in length, 5700 acres in area, at top water level, with a total storage of 265,000 acre feet, and a usable storage of 100,000 acre feet.

Travers dam in Alberta. The spillway and main supply canal to the Little Bow reservoir are shown

canals cross coulees, four of them are 8ft 6in in diameter and the fifth has a 10ft 6in diameter and a length of 4810ft.

The travers dam was built on the Little Bow River for the primary purpose of replacing 6 miles of precarious side-hill canal between Lake McGregor and Little Bow reservoirs, but also to increase water storage for the whole project. The dam is a rolled earth-fill structure containing 4,500,000 cubic yards of earth, rock and gravel, with a length of 3000ft and a base width of 1000ft. It has a maximum height of 140ft. There is a 960ft reinforced concrete spillway, capable of discharging 7700 cusecs at the east end of the structure. To the east of this spillway there is an outlet control structure, comprising seven reinforced conduits with a maximum capacity of 2700 cusecs on the main canal which supplies the Little Bow reservoir.

The 6 miles of old side-hill canal, referred to above, carried only 400 cusecs and the full development of the project will call for a capacity of 1800 cusecs ; hence the construction of the Travers dam as a key structure in the system of reservoirs and canals was considered essential.

Tenders for the construction of the dam and reservoir were called in May, 1951, and the Emil Anderson Construction Company was awarded the contract. Normally the flow of the Little Bow River is negligible after the spring run-off, and it was planned that the flow would be diverted into a 4ft diameter culvert until the dam was high enough to enable the reservoir to absorb the inflow. The 1952 run-off was abnormally high throughout the season, however, and it was not until September that it was found possible to close the river channel to divert the flow through the conduit. The conduit was left open during the winter to carry the spring run-off and was plugged with alternate plugs of concrete and bentonite in May, 1953, the spring run-off appearing to be past. However, very heavy rains raised the level of the reservoir at an unexpectedly high rate, and in order to avoid

Locomotives for Sub-Arctic Railway

One of the most northerly railways in the world has recently taken delivery of two new diesel-electric locomotives which have been specially equipped for the sub-Arctic conditions. These locomotives were manufactured by the General Electric Company of America and they will replace steam locomotives in the haulage of freight and passengers between the Alaskan port of Skagway and Whitehorse, Yukon Territory.

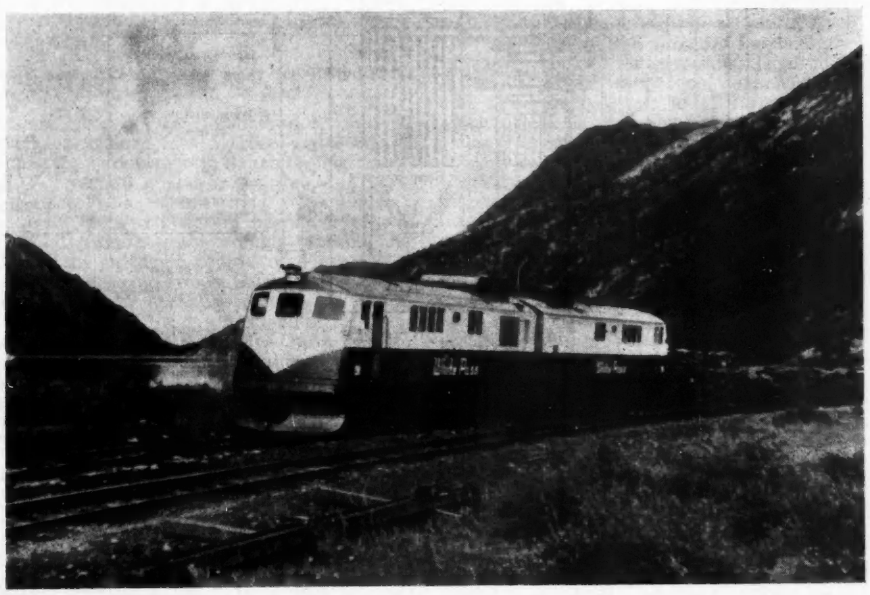
This 110·7-mile long 3ft gauge railway of the White Pass and Yukon Corporation runs through mountainous country with uncompensated gradients of 3·9 per cent and maximum curvatures of 24 deg. Winds of gale force are quite common and the temperatures to be met are often 65 deg. below zero. The line passes through an area which experiences some of the worst climatic conditions in North America ; White Pass being a region of particularly severe blizzards.

The design of the new locomotives permits the engineers to enter the engine compartment directly from the cab in inclement weather for inspection and maintenance purposes. The reinforced nose section of the cab is sloped to provide for the high stresses involved upon encountering heavy snow slides, and a snow plough is installed on the bottom of the cab platform. The locomotives are capable of negotiating 26 deg. curves when coupled for multiple unit operation.

In full working order each locomotive weighs 167,400 lb and is carried on two three-axle bogies, each axle being motor driven. The six-cylinder, supercharged Alco diesel engine fitted is rated at 800 h.p. at 1000 r.p.m. and is directly coupled to the main generator and an air compressor. The auxiliary equipment, consisting of an exciter and a standby generator, is belt driven from the main generator. With a 30 per cent adhesion the locomotive has a tractive effort of 50,220 lb, whilst the tractive effort at continuous motor rating is 24,000 lb.

Provision is made for the addition of alcohol to the brake compressor inlet air during winter operation to prevent freezing of moisture in the train lines and reservoirs.

To meet the severe winter conditions it was necessary to supplement the " Vapor-Clarkson " water heater, which is used in normal operation to maintain the correct water temperature in the coolant system, with a method of preheating that would keep the coolant at the higher operating temperature necessary during the periods of idling and standing by. The heating units fitted in the coolant system are connected to the main generator and come into operation when the engine is idling, and the throttle is in one of its first three notches.



Two 800 h.p. diesel-electric locomotives operating as a single unit on the White Pass and Yukon Railway

Super-Critical-Pressure Steam-Electric Power Station

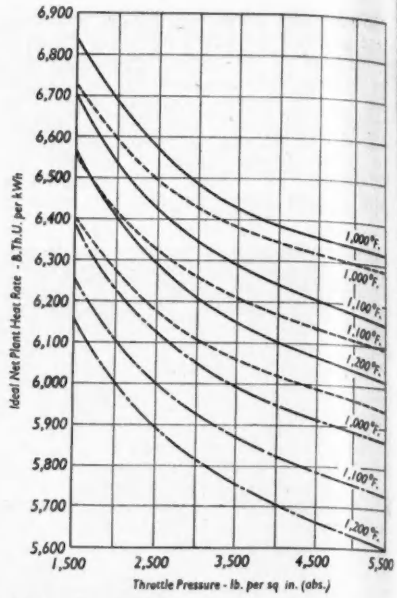
BY OUR AMERICAN EDITOR

The recent decision by the Philadelphia Electric Company to build a super-critical pressure steam-electric power station at Eddystone, Pennsylvania, is considered to be of real significance to future developments in the field of power generation. The installation will comprise a Combustion Engineering boiler of Sulzer "Monotube" design operating at a pressure of 6000 lb per square inch gauge and a temperature of 1200 deg. Fah. These steam conditions are higher than those of any other existing or planned American installation. A 275MW, 3600 r.p.m. turbo-generator for the station is being built by the Westinghouse Electric Corporation. It is expected that the plant will have a net thermal efficiency approaching 40 per cent, with a heat rate of about 8400 B.Th.U. per kilowatt-hour.

TO keep pace with the growing demand for power in the rapidly expanding Delaware Valley industrial area, the Philadelphia Electric Company recently announced its plans for a steam-electric power station that will constitute a major technological advance in power generation. The single boiler and turbo-generator unit will operate at a higher steam pressure and temperature and will have a capability greater than any comparable installation in the United States. It will use steam at pressures well in the super-critical range and employ two stages of reheat, and is expected to become the most efficient plant in America. The new power station will be situated at Eddystone on the Delaware River, 2 miles north-east of Chester, and will represent an initial investment of about 45,000,000 dollars. This area is characterised by a concentration of heavy industry, including locomotive and automobile manufacturing, shipbuilding, paper and chemical industries, and oil refineries which, combined with others in this area, make this section one of the major industrial centres in the United States.

It is of interest to note that the Delaware Valley is witnessing its greatest industrial expansion in years. As a result of this expansion, the Philadelphia Electric Company's industrial sales of electricity are growing at a rate of 7 per cent annually. The population in the Valley increased 15 per cent from 1940 to 1950 and the forecast for the decade 1950 to 1960 indicates further growth, with estimates ranging up to a 20 per cent increase. This growth is also reflected in the acceleration of residential building. The company has added 186,000 electric customers in the last six years and residential sales of electricity are growing at a rate of 8 per cent annually. The present construction plans of the company demonstrate a conviction that industrial, commercial and residential expansion will continue. In 1959, when the new 275MW unit will be in operation, it will represent slightly more than 10 per cent of the system peak load capacity. In the case of an isolated utility system, a unit of this size might be considered too large in terms of reserve requirements. However, since the Philadelphia Electric Company operates as part of the closely integrated Pennsylvania-New Jersey grid, the inter-connection peak load can be used as a basis for determining reserve requirements.

In accordance with accepted American generating practice, a "spinning reserve" must be carried to protect against the greatest hazard, either a forced outage or an error in estimating the load at any time of the day. Operating experience has shown that a spinning reserve of 4½ per cent of the inter-connection peak load will give adequate protection against load curtailment because of errors in daily load estimates. Since 4½ per cent of the estimated inter-connection peak load for 1959 will be 400MW, the loss of a 275MW generating unit will be amply covered. Hence, this large unit becomes a very logical addition to the company's system, since service continuity will not be jeopardised nor will the inter-connection reserve requirements be increased. Because of the low expected heat rate and because the supply system includes only about 10 per cent hydro-electric capacity, this unit should operate at a relatively high load factor during its life.



Heat rates are based on :—
(1) Each stage to reheat to initial steam temperature.
(2) Infinite feed heat stages to saturated temperature of quarter pressure.
(3) Exhaust pressure 1·5in Hg absolute.
(4) Gross generation minus only ideal B.F. pump power.
———— One reheat at quarter pressure.
— — — — Two reheats at one-quarter and one-sixteenth pressure.
—— — —— Infinite stages of reheat to pressures resulting in dry and saturated exhaust steam.

Fig. 2—Ideal net plant heat rates plotted on the basis of throttle pressures

Choice of Size of Generating Set

It is well known that a cycle using super-critical initial steam pressure, with its correspondingly small specific volume, permits optimum turbine efficiency only with units of large output. For this reason and due to the cost economies inherent in large machines, a unit of 275MW generating was chosen. Its net output to the company's grid will be 250MW. A turbo-generator of this capability has long been considered feasible providing that at least the low-pressure turbine element operated at only

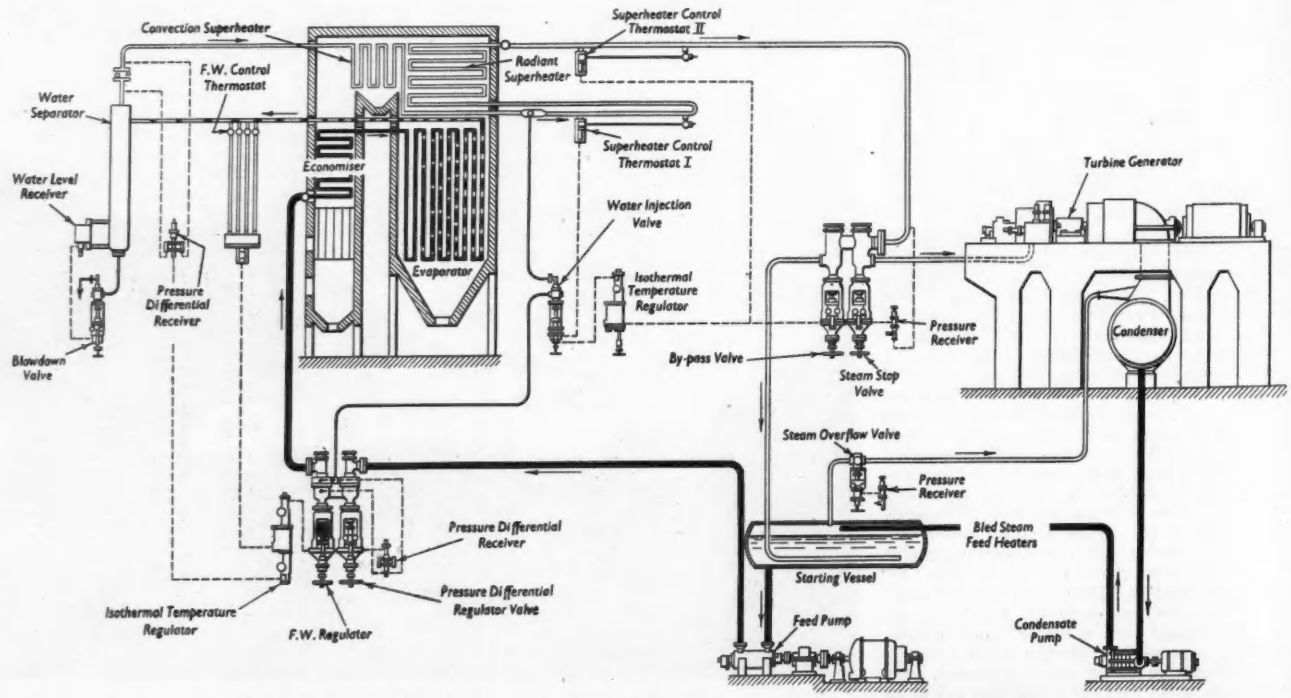


Fig. 1—Diagrammatic arrangement of Sulzer "Monotube" super-critical-pressure boiler installation

1800 r.p.m. More recently, however, developments relating to 3600 r.p.m. turbines and generators have enabled such units to satisfy most conditions of industrial power generation. It has been well established that these higher speed turbines are particularly adapted to use with advanced inlet steam pressures and temperatures. The major problem, as far as the turbine is concerned, has been to provide sufficient exhaust blade annulus to handle the enormous volumetric steam flow at this end with an acceptable leaving loss. This problem became a matter of developing larger exhaust stage blading, providing multiple exhaust steam flow paths and adopting improved thermal cycles which reduce the exhaust steam flow in terms of pounds per kilowatt-hour.

The development of large-size electric generators has kept pace with the development of turbines. Following the adoption of hydrogen cooling, the manufacturers introduced progressive increases in ventilating gas pressure. Finally, the development of inner-cooling has placed the cooling medium in direct contact with bare copper conductors in both the stator and the rotor. As a result, the rotor forging for the 275MW, 3600 r.p.m. generator will be smaller in diameter than many which are already in successful service at the same rotative speed, including a 125MW unit at the Delaware power station of the company.

Many forecasts have been made of the plant thermal gains made possible by increased steam pressures, initial and reheat temperatures and multiple stages of reheat. An approach based upon the theoretically possible heat rate for any assumed operating cycle has proved interesting and may also prove to be a good guide to the actual potential. In developing the anticipated heat rate of the new installation, the ideal cycle was taken as one having no losses in any of its components. The power required by an ideal boiler feed pump raising cold condensate to throttle steam pressure was then deducted from gross generation. Of course, the heat equivalent of such power consumption is added to the feedwater during compression. Regenerative feed heating was assumed under all conditions, based upon an infinite number of heating stages to a final temperature of compressed water equal to saturation at 25 per cent of the throttle steam pressure. This final feed temperature criterion approximates to that used in practice. The accompanying graph (Fig. 2) shows ideal net plant heat rates against throttle steam pressures from 1500 lb to 5500 lb per square inch absolute, with temperature and number of reheat stages as parameters, for reheat in each case to initial steam temperature and for 1·5in Hg absolute exhaust pressure. Single stage reheat is assumed to be at 25 per cent of the throttle steam pressure, which closely approximates to common American usage. For two stages of reheat the first is at 25 per cent of the initial pressure, and the second is at 25 per cent of the first reheat pressure. Small departures from these levels have been found to have little effect on the overall result.

Carrying this investigation to an extreme, the theoretical influence of infinite stages of reheat is also shown. This is really isothermal expansion to that pressure, which, in an ideal turbine, would produce dry and saturated exhaust at 1·5in Hg absolute exhaust pressure.

The significance of these curves is shown by a comparison of ideal net plant heat rates with numerous modern plant heat rates obtained under actual conditions. The ratio of actual plant heat rates to ideal values for one stage of reheat was found to lie in a band about 1 per cent wide in the region of 73 per cent of the ideal. This same percentage holds also for calculated values of super-critical pressure cycles with two stages of reheat. It appears reasonable to assume that this relationship may be generalised, and the statement be made that the relationship between any two of the ideal curves represents the relative realisable gain in going from one set of conditions to the other.

Boiler Design

The generation of steam at super-critical pressures makes necessary some modifications of conventional high-pressure water tube boiler design. In 1953 the Combustion Engineering Company entered into a licence-and-technical-assistance agreement with Sulzer Brothers, Ltd., of Winterthur, a firm which has had wide experience with the so-called " once-through " boilers. The accompanying diagram (Fig. 1) is included to indicate the working principle and method of automatic control of a sub-critical pressure plant employing a Sulzer " Monotube " steam generator. It should be clearly understood that in adapting the principle shown to super-critical conditions, a number of changes will be made in the controls and the equipment required.

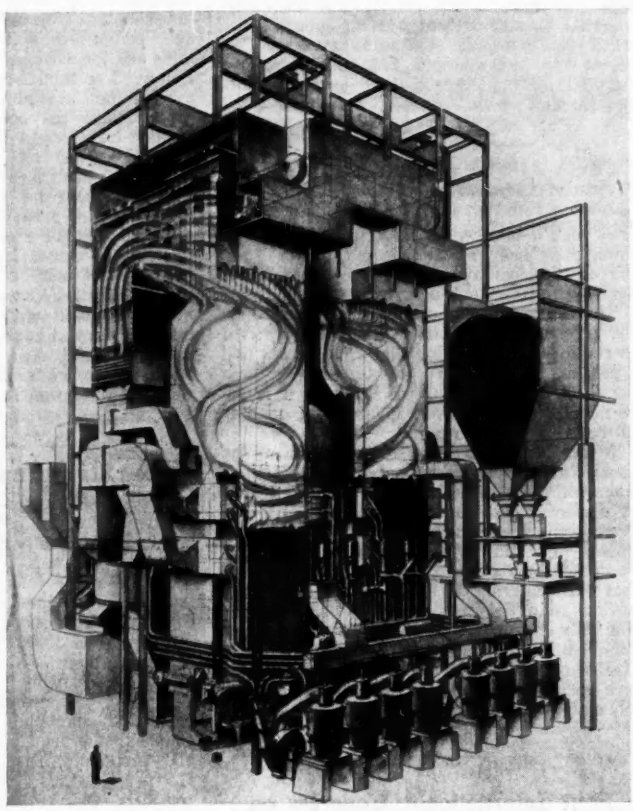


Fig. 3—Artist's impression of super-critical-pressure boiler for Eddystone power station of Philadelphia Electric Company

Under normal working conditions at sub-critical pressure the feed water leaving the starting vessel is supplied by the feed pump and reaches the steam generator by passing through the pressure difference regulating valve and the feed water regulator. It first flows through the economiser and goes directly to the evaporator section, where all but a small part of the water is transformed to steam. This mixture of steam and water is next conveyed to the separator, where the residual water is removed. The steam, after passing through a flow metering device, which provides one of the impulses for the feed water regulating valve, then enters the convection superheater and finally attains the desired temperature in the radiant superheater. Steam at the proper temperature and pressure conditions will then flow through the stop valve to the turbine. The feed water supply is automatically governed by a three-component regulating device. The first and second impulses are taken from the feed water and steam flows, whereas the third impulse is established by the feed water control thermostat, thus adapting the feed water quantity to the heat input.

For regulating the final steam temperature, one or more superheater control thermostats, which are arranged along the superheater, control the water injection. The stop valve serves as an automatic turbine stop valve and, together with the by-pass valve as a safety device. These valves protect the turbine against abnormal steam pressures and temperatures. In abnormal conditions and during the starting period, the stop valve closes automatically and the steam or water-and-steam mixture is led through the automatic by-pass valve to the starting vessel. With this device any undue loss in condensate is avoided and the whole tube system, especially the superheater, is automatically protected during starting and other unstable periods by maintaining flow. In extreme cases, in which the entire quantity of steam cannot be condensed in the starting vessel, the excess steam is led through a steam overflow valve to the main condenser. Loss of feed water supply or loss of oil in the control system automatically cuts off the fuel and air supply, the pressure being gradually reduced at the same time.

The adaptation of the " Monotube " design to the super-critical pressure cycle will require modifications of the working principle and method of automatic control just described. To this end intensive studies are being made both in the United States and in Switzerland, where Sulzer Brothers, Ltd., has been carrying out a comprehensive testing programme. Using a test boiler operated under super-critical conditions, engineers are ascertaining water conditioning requirements and operating characteristics of certain component parts of the " Monotube " steam generator. Considerable basic design information has been determined, and the test results to date have proved encouraging.

In many respects, the steam generator to be employed represents a logical evolution of the design employed in the controlled-circulation boiler at the Cromby power station of the Philadelphia Electric Company, and many of the basic details will be patterned after that unit. Like the Cromby unit, it will have two separated furnaces with firing through tilting tangential burners. An artist's impression of the boiler design is reproduced in the accompaying illustration (Fig. 3).

The square furnaces will be over 100ft high and will have conservative heat-release rates. The separation of the furnaces simplifies the structural problems of supporting large units. It enables central supporting columns to be used and permits access to all furnace walls. Much experience has now been gained with platen superheater and reheater surfaces. Radiant wall surface will also be employed along with a convection finishing section on the primary superheater. Experience with small-diameter tubes in controlled-circulation boilers has suggested their use in the super-critical pressure unit. This tubing weighs less and has much thinner walls, with a resultant reduced thermal stress in the tubes.

In principle, the Sulzer " Monotube " steam generator consists of a single tube which is led in repeated convolutions through the flue gases and around the combustion chamber. The feed water is introduced at one end of the tube and leaves at the other end in the form of superheated steam at a fixed pressure and temperature. In practice the steam generator consists of several circuits in parallel. The velocity of the working medium is kept high enough in all sections of the tube system so that efficient cooling of the tube walls is ensured in both the heating and in the superheating zones. The problem of distribution through " Monotube " circuits is simplified in the super-critical region because mixtures of steam and water do not occur.

The arrangement of the heating, superheating and reheating surfaces has been governed by the increased duty required of the superheater and the double-stage reheaters. At the Cromby station, for example, 40 per cent of the heat is absorbed by superheater and reheater surface. In the super-critical pressure unit this heat absorption will rise to 65 per cent of the total heat input, necessitating a large proportion of radiant surface to be employed in superheating and reheating.

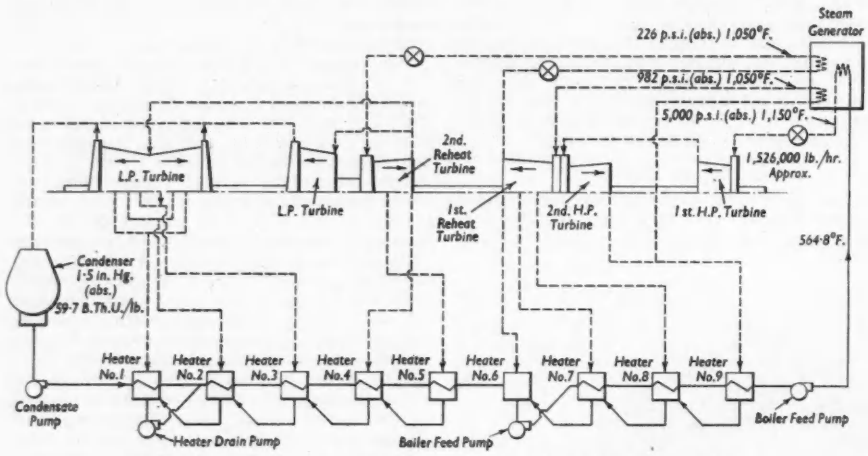


Fig. 4—Diagram of proposed thermal cycle of Eddystone power station

The water supplied by the boiler feed pumps enters a conventional economiser after which it passes through water preheating surface situated in high heat-absorbing areas in the burner zone if the furnace. The zone in which the fluid changes from water to steam will be placed in surface with lower heat absorption rates. Superheating and reheating will be accomplished in a combination of convection surface, radiant-wall surface and platens. To regulate steam and water flow, the Sulzer system of automatic controls will be used. These controls are of oil-hydraulic design. In the boiler control system the water is pumped directly through the system by the boiler feed pump in proportion to steam flow with vernier control from steam temperature; the primary steam temperature is controlled by desuperheating spray under an accurate multiple thermostatic control, and the reheat temperatures are controlled by burner tilt. Automatic by-pass and stop valves, providing pressure and temperature limits, ensure start-up and emergency protection of the superheater, reheaters and turbine, functioning as required with the usual intercept valves.

Turbine Design

The accompanying cycle diagram (Fig. 4) shows the thermal cycle which is to be employed in the initial phase of operation of the power station. The design of the plant has been based upon raising the throttle steam temperature from 1150 deg. to 1200 deg. Fah. after a preliminary period of service. This temperature change is expected to result in a reduction in the plant heat rate of approximately 60 B.Th.U. per kilowatt-hour. Under the initial operating conditions shown in the diagram, the heat rate of the installation should not exceed 8400 B.Th.U. per kilowatt-hour. In arriving at the steam condition selected, consideration was given to initial pressures as high as 8000 lb per square inch, and temperatures of 1250 deg. Fah. It is believed that such conditions hold promise for future development. In planning the installation, the reheat temperatures were limited to 1050 deg. Fah. on the basis of the thermal gain evaluated against the relative equipment cost. Two-stage reheat was incorporated instead of the now common single-stage method, because it becomes attractive economically with the higher initial steam conditions involved.

The Westinghouse Electric Corporation will supply the turbo-generator as well as the condenser, the condensate- and circulating-water pumps, and the feed water heaters. While the exact design has not yet been finalised the present scheme was initiated on the basis of a single-shaft, tandem-compound turbine and a single generator. Consideration is also being given to a cross-compound turbo-generator arrangement, with the high and low-pressure shafts operating, respectively, at 3600 r.p.m. and 1800 r.p.m. Due to the reduced exhaust stage leaving loss, such a unit would, of course, result in a lower plant heat rate at high output rates, and the resulting fuel savings are now being evaluated against the associated higher capital cost.

The boiler feed pumps are being designed by the Ingersoll-Rand Company and are expected to employ a balanced impeller arrangement and "packless" seals. To obtain the required pressure of about 6000 lb per square inch, it will be necessary to go to very high speeds, possibly of the order of 6500 r.p.m.

It is felt that the successful operation of the super-critical cycle will depend to a considerable extent on attaining a feed water practically free of dissolved gases and solids. The estimated ½ per cent make-up for this installation and possibly a portion of the condensate as well will be treated by a demineralisation plant to ensure that water entering the boiler cycle is of a purity of less than 0·1 parts per million of solids. The only chemicals expected to be present after demineralisation treatment will be certain volatile alkalis required to prevent iron and copper pick-up in the pre-boiler system and to remove any oxygen which escapes the de-aeration stage.

First International Congress on Air Pollution

THE first international congress on air pollution, which was sponsored by the American Society of Mechanical Engineers as part of its seventy-fifth anniversary celebrations, was held in New York in March. The main speaker at the meeting was Sir Hugh E. C. Beaver, managing director of Arthur Guinness, Son and Co., Ltd., and chairman of the Government committee on air pollution in the United Kingdom. Giving the annual Calvin W. Rice Lecture of the A.S.M.E., Sir Hugh emphasised that air pollution programmes and legislation would remain ineffective until public opinion had grown strong enough to support their enforcement. He briefly recapitulated the long history of air pollution in Great Britain and of the development of public opinion leading to agitation and action. He showed how sporadic, disjointed, and ephemeral much of this agitation and effort had been. Throughout the nineteenth century, the great bulk of opinion was seen to be either apathetic to the pollution, or definitely hostile to act on what would affect either the individual or industry. Throughout this period, numerous committees had studied the problem and a good deal of legislation had been enacted, but without any material improvement. His paper contrasted the very different state of feeling at the time of the last two committees of investigation which had been appointed in Great Britain: the Newton Committee in 1920 and the Air Pollution Committee of 1953, of which he was chairman. Sir Hugh indicated how much public opinion had affected both the methods of operation of these two committees and the form and nature of their reports. He further noted the very different receptions that had been given to the two reports and, in rather greater detail, considered the operations of the 1953–1954 committee and its recommendations, including the proposal to establish a "Clean Air Council." Looking toward the future, Sir Hugh closed his lecture with the following remarks: "Now I cannot say what action will eventuate. It has often happened before that initial approval of a proposition has broken down into piecemeal criticism and opposition, as the implications have been more closely studied by individual interests. But I can say that I do not believe recommendations of this nature would have had the slightest chance of being accepted either by Government or by industry or by the ordinary householder or by the public press twenty years ago, perhaps even five years ago. Now, the odds are, I believe, quite strong that action will follow. I so think because it seems to me quite evident that this is now the public wish; because at last there has been that growth of public opinion on which, as I said at the outset, everything in the end rests. What is the moral of all this? I confess it is not easy to say. I think we must accept that public opinion, in spite of all the arts of propaganda and education—and all these must be used—public opinion even in the best of causes largely takes its own time, and anyhow takes considerable time to reach boiling point. What, I think, emerges is that propaganda and education have often been too fragmentary and haphazard, too little concerted and sustained." At a banquet held at the Hotel Statler honorary membership in the A.S.M.E. was conferred upon Sir Hugh Beaver by D. W. R. Morgan, president of the Society.

United States Ten-Year Highway Plan

THE advisory committee set up by President Eisenhower to study a ten-year highway programme has recently submitted its report, which contains proposals for the modernisation of 40,000 miles of inter-state highway through a self-liquidating financing programme. The recommendations made include expenditure of 27,000 million dollars on the national system of inter-state highways. Of this amount 2000 million dollars would be provided through state and local participation. State-controlled toll roads or the inter-state system are also suggested, as well as continued federal assistance for primary and secondary road systems amounting to 525 million dollars annually. The committee considers that if the Federal Government increased its share of the total construction programme to some 30 per cent of the total, the states and local units of government would correspondingly increase their share.

A major provision of the report is the proposed establishment of a Federal Highway Corporation as a separate government agency to issue bonds which would finance the federal share of the road building programme. It was proposed that this Corporation should have a board of directors composed of three citizens appointed by the President, with the Secretaries of the Treasury and Commerce Department as ex-officio members. The Secretary of Defence would also serve in an ex-officio capacity on matters related to the location of highways. If established, the board of the Corporation would be responsible for financial policy and would serve, when necessary, as an appeals board to resolve any major points of difference arising between federal and state authorities.

In discussing the U.S. vehicle fleet, the growth of which made necessary the urgent implementation of the highways plan, the committee reported that, according to estimates, by 1965 an increase in the vehicle fleet of 40 per cent should raise the total registrations to 81,000,000. To accomplish the 101,000 million dollar programme envisaged in the ten-year plan will require doubling the present road construction programme.

Industrial and Labour Notes

Shortage of Technicians

The annual conference of the Association of Engineering and Shipbuilding Draughtsmen was held at Whitley Bay last week-end. In his presidential address, Mr. J. L. Mitchell commented that there were not in this country sufficiently big reserves of technicians to meet the increasing demands resulting from scientific advance.

Industry, Mr. Mitchell said, was still not dealing adequately with the problem, with the result that every year hundreds of technicians left and went overseas or to other industrial fields in order to obtain more lucrative employment. For the same reason, he added, not enough boys were being attracted to apprenticeship in the engineering industry. It was unrealistic, Mr. Mitchell claimed, to expect them to undergo a thorough apprenticeship, with evening study, in order to qualify for jobs with unsatisfactory prospects when their contemporaries who entered semi-skilled or unskilled occupations could earn nearly as much.

During the conference a motion was carried urging a campaign against the working of overtime, on the ground that overtime tended to obscure the need for a proper basic weekly wage. Another motion, which was also carried, instructed the executive of the Association to open negotiations with employers for the payment of bigger rates for overtime work.

Employment and Unemployment

The Ministry of Labour's latest report on the employment situation in Great Britain says that, at the end of February, the number of people in civil employment was 22,745,000 (15,094,000 men and 7,651,000 women). This was 19,000 more than at the end of January. The total working population of the country increased by 8000 during February.

An analysis of the civil employment figures shows that the number at work in the basic industries in February was 3,970,000, or 6000 more than in the preceding month. The increase occurred in the gas, electricity and water supply industries and in transport and communications. In the coal mining industry, the number of wage earners on the books at the end of February was 708,000, the same as a month earlier. In the manufacturing industries, there was an addition of 10,000 during February to the labour forces, bringing the total to 9,216,000. Most of this increase was in the engineering, metal goods and precision instruments group, the number employed there being 2,740,000, compared with 2,606,000 a year earlier. In vehicle manufacture, there were 1,223,000 people employed in February, compared with 1,167,000 in February last year. The principal change in other industries than manufacturing was in building and contracting where 1,430,000 people were employed in February, an increase of 9000 compared with the preceding month.

The Ministry's report on unemployment states that on March 14th there were 269,911 people registered as out of work, compared with 281,632 on February 14th. The March figure included 18,614 who were reported to be temporarily stopped. The Ministry states that, in the week ended February 26th, about 40,000 operatives in manufacturing establishments rendering returns were reported to be on short time, losing thirteen and a half hours each on the average. On the other hand, there were 1,615,000 operatives working, on an average, eight hours overtime in that week.

British Industries Fair

It has been announced that from 1956 onwards the British Industries Fair is to be held at two different times of the year. The first show will be at Earls Court, London, from February 22 to March 2, 1956, and the second, at Olympia, London, and Castle Bromwich, Birmingham, from April 23 to May 4, 1956.

Mr. Kenneth Horne has been appointed full-time managing director of the Fair, and after this year's B.I.F.—which is to be held at Olympia and Castle Bromwich from May 2nd to 13th—he will take over from the present general manager, Mr. J. L. Reading. Mr. Horne is one of the six directors of British Industries Fair, Ltd., the company which was formed last year to organise the Fair, a function hitherto undertaken by the Board of Trade. The intention is that at the Earl's Court section of the Fair in February the exhibits will comprise consumer goods, whose main selling season is the spring. At Olympia in May there will be shown the products of light industries such as packaging, chemicals and office appliances, and at Castle Bromwich the products of the hardware and heavier engineering industries will continue to be displayed. It is realised that the changes may involve some adjustment between the industries showing in London and Birmingham. The fair management committee of the Birmingham Chamber of Commerce will continue to manage the Birmingham section of the Fair.

Sir Ernest Goodale, chairman of British Industries Fair, Ltd., has expressed the view that the changes of date will meet the major criticisms of a number of industries that the Fair has been held at the wrong time of the year.

Industrial Disputes

It is stated in the current number of the *Ministry of Labour Gazette* that during February there were in progress in the United Kingdom 238 stoppages of work resulting from industrial disputes. These stoppages involved, directly and indirectly, about 47,800 workers and caused an aggregate loss of 156,000 working days. Most of the stoppages, 159 in all, occurred in the coal mining industry, where 103,000 working days were lost in February by 32,900 workers.

The Ministry says that of the disputes leading to stoppages of work which began during February, twelve arose out of demands for advances in wages, and eighty were concerned with other wage questions. There were six disputes about working hours, twenty-nine respecting the employment of particular classes or persons, eighty-three disputes over other questions as to working arrangements, and seven over questions of trade union regulations. Six of the stoppages in February were in support of workers involved in other disputes.

In the first two months of this year, there were 404 stoppages of work in the United Kingdom through industrial disputes. They involved 89,300 workers and caused an aggregate loss of 247,000 working days. In the comparable period of last year, there were 340 stoppages, involving 86,700 workers and resulting in an aggregate loss of 258,000 working days.

Investment Allowance on Second-Hand Machinery

The British Association of Machine Tool Merchants has submitted a memorandum to the Chancellor of the Exchequer on the subject of investment allowances in relation to used machinery. This memorandum points out that an important reason for limiting the investment allowance to new machinery was stated to be the possibility that tax evasion or frauds would arise from applying it to used machinery. But it is suggested that such a possibility could be avoided by withdrawing the allowance if the machinery was sold, say, within three years of purchase. It might also be considered, the memorandum adds here, that, to rank for investment allowance, second-hand machinery should be less than a certain maximum age and more than a certain minimum value. In order to avoid private arrangements between traders and associates, it would be possible to limit the investment allowance to machinery bought through a *bona fide* merchant or dealer of second-hand machines, or on valuation by a recognised valuer or merchant.

Another point raised in the memorandum is that the investment allowance generally has had a depressing effect on the second-hand machine tool industry and, what is more important from the point of view of the country and industry generally, it appears to be stimulating the demand for new machines so that delivery dates are being increasingly delayed, being now as much as two to three years in certain categories of machinery. The longer the delay in delivery, it is urged, the greater will be the loss of production capacity in the case of firms which would expand by the use of second-hand machinery but which in present circumstances will wait in order to obtain investment relief on new machines. It is impossible for the average small sub-contracting firms, the memorandum continues, to order ahead in this way because the nature of their trade prevents them from seeing so far ahead what will be their requirements. A small business of this kind contracts more or less immediately with the bigger firms to produce certain parts, and if it has not the equipment for doing this will not obtain a contract. Furthermore, the fact that industrialists may not be able to obtain a reasonable price for second-hand machines must in many cases make them reluctant to buy new machines and sell their old ones.

It should also be borne in mind, the memorandum says, that the great majority of the small businesses which form the bulk of industry in this country rely very much in their expansion programmes on second-hand machinery. The grant of adequate investment allowance for second-hand machinery would greatly assist the expansion of small and medium-size businesses of this sort where the average value of the machine is in the neighbourhood of £400, purchased second-hand.

Foundry Ventilation and Dust Control

The British Cast Iron Research Association is to hold a conference on foundry ventilation and dust control from April 27th to 29th, at the Hotel Majestic, Harrogate. This conference, it is stated, will emphasise in particular the measures to be taken to meet the new statutory regulations relating to dust and fume with which all foundries must comply as from January 1st next.

Four years ago, the British Cast Iron Research Association formed a Foundry Atmospheres Team to investigate the control and elimination of dust and fumes in various foundry operations and to study the possibilities of improving foundry ventilation generally. The forthcoming conference, it is hoped, will provide an opportunity to survey progress which has been made so far, particularly in the control of dust at the knock-out station and in fettling and grinding operations. Other contributions to the proceedings of the conference will include papers on the suppression of dust in specific operations, foundry lighting practice, and on good housekeeping in the foundry.

Mr. S. H. Russell, president of the Association, will take the chair at the opening session of the conference at 2 p.m. on Wednesday, April 27th. At that session, an address on "Health and Safety in the Foundry Industry" will be given by Sir George Barnett, H.M. Chief Inspector of Factories.

Research in the Glass Industry

In October last, the British Glass Industry Research Association was formed, with the encouragement of the Department of Scientific and Industrial Research. It is now in the process of taking over the research work which has been carried on, since the first world war, by the Department of Glass Technology of the University of Sheffield. The British Glass Industry Research Association and the Department of Glass Technology are now separately administered, although they share the same university building at Elmfield, Northumberland Road, Sheffield, 10. Dr. R. G. Newton has been appointed director of the Association and Dr. D. K. Hill, assistant director. At the same time, Mr. R. W. Douglas has been appointed to the chair of glass technology at Sheffield University, in succession to Professor H. Moore, who is retiring.

Personal and Business

Appointments

SILENTBLOC, Ltd., Manor Royal, Crawley, announces the appointment of Mr. J. W. Moore as general manager.

A. BOAKE, ROBERTS AND CO., Ltd., Stratford, London, E.15, states that Mr. T. A. Mason, works manager, has been appointed a director.

MR. H. T. GREATOREX has been appointed assistant head of the engineering information department of the British Broadcasting Corporation.

MR. F. A. HURST, chairman and managing director of Samuel Osborn and Co., Ltd., Sheffield, is to be installed as president of the Sheffield Chamber of Commerce on April 28th.

THE BRITISH THOMSON-HOUSTON COMPANY, Ltd., Rugby, has announced a re-organisation of its traction department. Mr. W. B. G. Collis is the manager of the department, Mr. J. H. Cansdale is the deputy manager, and in addition will be primarily responsible for all contracts. Mr. M. W. T. Rees has been appointed assistant manager (projects).

THE NATIONAL COAL BOARD states that Mr. R. A. Howson, deputy divisional marketing director of the West Midlands division, is to succeed Mr. V. J. Wilkes as marketing director. Mr. H. Dudley, head of the industrial relations branch at the Coal Board's headquarters, is transferring to the South-Eastern division to succeed Mr. G. W. Twigger as labour director.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., Trafford Park, Manchester, states that Mr. W. N. Kilner, M.I.E.E., has been appointed chief engineer of the newly-formed turbo-generator engineering department. Mr. C. P. Holder, M.I.E.E., has been appointed assistant chief engineer of the plant department, and Mr. E. Nicholson, A.M.I.E.E., has been appointed assistant chief engineer of the switchgear department.

Business Announcements

THE CHLORIDE ELECTRICAL STORAGE COMPANY, S.A. (PTY.), Ltd., has opened a new battery factory at East London, South Africa.

BESSON AND ROBINSON, Ltd., is now established in a new factory in the East Industrial Estate, Harlow, Essex (telephone, Harlow 25231).

THE AEROGRAPH COMPANY, Ltd., states that its sales division has been transferred from Lower Sydenham, to 47, Holborn Viaduct, London, E.C.1 (telephone, City 4361).

TURBOMACHINES, Ltd., 17, Station Road, Egham, Surrey, has been formed to provide a design and consulting service in gas turbine machinery. The directors are Mr. J. C. Barr and Mr. J. C. Grey.

JOHN YUILLE (METAL WORKS), Ltd., Scottish Industrial Estate, Hillington, Glasgow, S.W.2, states that its press tools, jigs and fixtures are now produced under the registered trade mark "Ursus."

THE ENGLISH ELECTRIC COMPANY, Ltd., states that it has purchased from the Canadian Government a factory at Scarborough, near Toronto. The buildings have a floor area of 180,000 square feet. The factory was built in 1952 by the John Inglis Company, Ltd., for the Department of Defence Production. It will continue at present to be operated by the John Inglis Company, Ltd., and the English Electric Company, Ltd., for the Royal Canadian Navy escort vessel programme. The controlling interest in the John Inglis Company, Ltd., and its subsidiary, the English Electric Company of Canada, Ltd., was acquired by the English Electric Company, Ltd., in 1950.

Miscellanea

EXPANDED METAL EXHIBITION.—To illustrate the many industrial, commercial and domestic uses to which expanded metal is being put, the Expanded Metal Company, Ltd., of West Hartlepool, is holding a three-day exhibition of its products at the Birmingham Exchange Engineering Centre, Stephenson Place, Birmingham, from April 19th to 21st.

EARLESTOWN WAGON WORKS SCHOOL.—At the beginning of the month, Lord Rusholme, chairman of the London Midland Area Board of British Railways, opened the latest apprentices' training school at Earlestown Carriage and Wagon Works. This school is one of a number being introduced by the London Midland Region to provide opportunities for boys wishing to follow a railway technical career.

ZINC INGOTS AND SLABS.—The Board of Trade announces the issue of an open general export licence authorising the export to any destination other than China, Macao, North Viet Nam or Tibet of specified brands of zinc ingots and slabs (or plates). The open general licences for copper goods and for iron and steel goods have been revised to exclude North Viet Nam from the permitted destinations. China, Macao and Tibet are already excluded. This change is consequent upon the recently announced extension of export licensing control to cover all exports to North Viet Nam. These licences are dated April 7th, and come into operation on April 18th. Copies are obtainable from H.M. Stationery Office, Kingsway, London, W.C.2, and branches, price 2d.

WELDING ALUMINIUM.—A brochure recently published by the Northern Aluminium Company, Ltd., gives information on the modern argon tungsten arc and inert metal arc processes, including data on suitable alloys and on weld strength. It also includes tables giving in detail the recommended procedures for various types of weld.

LARGE STEEL ROPES.—Three very large steel ropes have been designed and manufactured by Wrights' Ropes, Ltd., of Birmingham. These ropes, which are destined for use in connection with a Continental hydro-electric undertaking, are over 2¾in in diameter and 1400ft in length. Each rope weighs 16 tons and has an actual breaking load of 325 tons. The ropes have been packed for shipment on reels 9ft in diameter and 7ft wide.

INSTITUTE OF METALS.—The adjudicators for the Institute of Metals students' essay competition have awarded first and second prizes as follows: first prize of Twenty-Five Guineas to Dr. A. P. Miodownik, student member, Battersea College of Technology, London, S.W.11, for an essay on "The Significance of Microhardness Testing"; second prize of Fifteen Guineas to Mr. Surindar Singh, student member, County Technical College, Wednesbury, for an essay on "The Kirkendall Effect."

BRIDGE RECONSTRUCTION ON THE EASTERN REGION.—With the electrification of the Shenfield-Chelmsford-Southend (Victoria) lines it has been found necessary to increase the clearances of several highway bridges over the railway track to accommodate the overhead electrical equipment. The spans of all the bridges to be rebuilt vary between 27ft 5in and 46ft 4in and they are of partially prestressed concrete slab construction according to the designs developed by the Eastern Region's civil engineering staff and similar to a number of bridges reconstructed on the Manchester-Sheffield-Wath lines.

COPPER SALES.—The Board of Trade announces that it has decided to sell up to about 45,000 tons of electrolytic copper over the rest of this year. Arrangements for the sale of part of this have already been made with the Rhodesian producers and their sales agents, and it is proposed to enter into early discussions with the trade about the disposal of the remainder. The intention is that so far as practicable the copper will be delivered and priced at an even rate. This copper is from the trading stocks remaining in the Government's hands after private trading was restored in 1953. The copper already sold is of Rhodesian brands.

SUMMER SCHOOL ON COMPUTERS AT IMPERIAL COLLEGE.—A four-week course on digital and analogue computers and their application to electrical engineering problems will be given at Imperial College, London, from May 31 to June 24, 1955. It is intended to acquaint electrical engineers with the computing facilities that are becoming available, to introduce them to the methods used for the solution of typical engineering problems, and to instruct them in the presentation of problems for computation. Further particulars can be obtained from the Deputy Registrar, City and Guilds College, Exhibition Road, London, S.W.7.

V.D.I. MEETINGS.—The design section of the Verein Deutscher Ingenieure is holding a meeting at Kassel on May 12th and 13th, at which scientists and practical designers will report on recent developments of joining elements and joining methods. A special meeting, entitled "Der Mensch im Kraftfeld der Technik," will be held by the V.D.I. in Münster on May 17th and 18th. As with the previous meetings on this topic, the purpose again is to survey the human and social consequences of technical progress, and to discuss how people everywhere might be educated to make use of technological possibilities. For full information, application should be made to V.D.I., Düsseldorf, Prinz-Georg-Strasse 77/79.

SMOKE REDUCTION IN INDUSTRY.—The National Industrial Fuel Efficiency Service and the Combustion Engineering Association are to hold a conference on "Smoke Reduction in Industry on the North East Coast," on Wednesday next, April 20th, at the Royal Station Hotel, Newcastle upon Tyne, beginning at 10 a.m. The object of this conference, which the Lord Mayor of Newcastle is to open, will be to show how the emission of smoke by industry can be reduced by the right selection and use of fuels and appliances. The conference fee for each person attending will be £1 1s., inclusive of buffet luncheon at the Royal Station Hotel, Newcastle, and including a copy of the proceedings of the conference, which will be issued in due course.

BRITISH EXHIBITS AT OVERSEAS TRADE FAIRS.—In view of the increasing number of British firms which are taking part in trade fairs overseas, the Board of Trade has issued a booklet which gives advice to British firms on how to make the most of exhibiting overseas, and which sets out the merits of some of the most notable trade fairs abroad. Drawing on the experience of several British manufacturers who have successfully shown their goods abroad, the booklet deals with such subjects as the choice of fair, methods of exhibiting, costs, publicity and public relations. It is illustrated with pictures of trade fairs in Paris, Cologne, Hanover, Milan and New York. The booklet, which is called *Trade Fairs Overseas*, is obtainable from Her Majesty's Stationery Office, price one shilling.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE.—At the annual general meeting of the West of Scotland Iron and Steel Institute, which is to be held at 39, Elmbank Crescent, Glasgow, this (Friday) evening, members' views are to be sought on a proposal to change the name to the Scottish Iron and Steel Institute. No formal decision on the matter, however, will be taken at the meeting. The council is inviting offers of papers for next session. Papers on steelworks engineering and on the metallurgy or production of iron and steel are welcomed. Prospective authors are asked to communicate with the Secretary of the Institute at the above address.

SEVENTH INTERNATIONAL FAIR AT LIEGE.—A large contingent of mining machinery and equipment, as well as metallurgical and mechanical and electrical engineering products, will be shown at the Seventh Liège Fair, which is to be held from April 23rd to May 8th. The uses of rubber in mining will be exemplified in numerous exhibits, and a reconstruction of a fully-equipped mining gallery will show the conditions in the Liège coalfield. In addition to the exhibition of industrial products, there will be a hall devoted to equipment used in the home, and another hall showing industrial design, packings and advertising. Special study sessions are being arranged by the Association of Liège Engineers (A.I.Lg.), the Association of Graduates of the Montifiore Electrotechnical Institute (A.I.M.), the Centre Belge d'Etude et de Documentation des Eaux, and the Association Technique de Fonderie de Belgique. Sessions will be included on industrial design and other topics. Fair vouchers and information may be obtained from Mattis Industries, Ltd., 252-255, Abbey House, 2, Victoria Street, London, S.W.1, or from Belgian Railways, 167, Regent Street, London, W.1, or from the Belgian Chamber of Commerce, Ibex House, Minories, London, E.C.3.

Launches and Trial Trips

RANWORTH QUEEN, trawler; built by John Lewis and Sons, Ltd., for Talisman Trawlers, Ltd.; length overall 113ft 6in, length between perpendiculars 100ft, breadth moulded 22ft, depth moulded 10ft 9in; one 15kW diesel-driven generator, one 10kW belt-driven generator; Crossley Mark H.R.N.6 diesel engine, 440 b.h.p. at 300 r.p.m. Trial March 9th.

SCOTTISH HAWK, oil tanker; built by the Greenock Dockyard Company, Ltd., for the Scottish Tanker Company, Ltd.; length between perpendiculars 512ft, breadth moulded 69ft, depth moulded 38ft 6in, deadweight 16,400 tons on 29ft 10in draught, service speed 14 knots; nine centre and eighteen wing cargo oil tanks, two cargo oil pump rooms, four 500-tons per hour cargo pumps, two 80-tons per hour stripping pumps, steam deck machinery; one 75kW steam-driven generator, two 150kW diesel-driven generators; Wallsend-Doxford oil engine, six cylinders 670mm diameter by 2320mm combined stroke, 6400 b.h.p., two boilers. Trial March 16th.

CORSTREAM, collier; built by the Burntisland Shipbuilding Company, Ltd., for William Cory and Son, Ltd.; length between perpendiculars 320ft, breadth moulded 46ft, depth moulded 22ft 4in, deadweight 4600 tons on 20ft draught; steam deck machinery, five cargo holds; North Eastern Marine "Reheat" triple expansion engine, 1100 i.h.p., taking steam at 220 lb per square inch from two cylindrical, multi-tube boilers, burning oil fuel under forced draught. Launch, March 22nd.

CRYSTAL BELL, bulk sugar and grain carrier; built by Cammell Laird and Co. (Shipbuilders and Engineers), Ltd., for the Sugar Line, Ltd.; length overall 460ft, length between perpendiculars 430ft, breadth moulded 61ft, depth moulded to upper deck 37ft 3in, deadweight 9500 tons, load draught 24ft 6in; five holds all forward of machinery space, Nos. 2, 3, 4 and 5 holds divided into three compartments by two longitudinal bulkheads, sugar or grain in centre compartments and No. 1 hold, wing compartments arranged to take grain at No. 2 hold, grain or water ballast at Nos. 3 and 4 holds, and oil fuel at No. 5 hold; steam deck machinery, one 25-ton and ten 10-ton derricks; two 75kW diesel-driven generators, one 20kW steam-driven generator; Wallsend-Doxford, four cylinder, opposed piston oil engine, 3300 b.h.p.; one composite exhaust gas and oil-fired boiler, one single-ended oil-fired cylindrical boiler. Launch, March 24th.

FOYLEBANK, cargo liner; built by Harland and Wolff, Ltd., for the Andrew Weir Shipping and Trading Company, Ltd.; length overall 455ft, length between perpendiculars 425ft, breadth moulded 59ft, depth moulded to shelter deck 38ft 3in; two complete steel decks, four main cargo holds, one 25-ton, fourteen 5-ton and two 3-ton derricks, electric deck machinery, three 175kW diesel-driven generators; Harland and Wolff two stroke, single-acting, opposed piston diesel engine, six cylinders, 620mm diameter by 1870mm combined stroke, two vertical boilers, one oil-fired and one exhaust gas-fired. Launch, March 24th.

HAMINEA, oil tanker; built by Smith's Dock Company, Ltd., for Shell Tankers, Ltd.; length overall 557ft, length between perpendiculars 530ft, breadth moulded 69ft 3in, depth moulded 39ft, deadweight 18,000 tons on 29ft 6in draught, service speed 14½ knots; thirty-three main cargo oil tanks, one cargo pump room, four 400 tons per hour cargo oil pumps, two stripping pumps; steam deck machinery, two 550kW turbine-driven alternators, one 200kW diesel-driven alternator; Hawthorn Leslie two-casing, double reduction geared turbine, steam supplied at 500 lb per square inch and 800 deg. Fah. by two Foster Wheeler "D" type boilers. Launch, March 25th.

British Patent Specifications

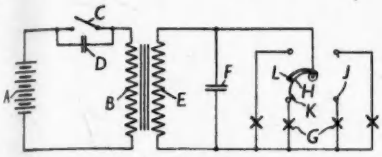
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

INTERNAL COMBUSTION ENGINES

725,619. June 10, 1953.—LOW VOLTAGE IGNITION SYSTEMS, Smitsvonk N.V., Leidschendam, Westvlietweg 121, The Netherlands.

According to the invention a low voltage ignition system for internal combustion engines has an ignition coil and an ignition condenser connected in parallel with the secondary winding of the coil, the condenser discharging via a spark gap connected in series with a single surface discharge spark plug or, in the case of a number of such plugs, with each plug in turn in which the length of the spark gap is automatically adjusted in dependence on the speed of the engine. Referring to the drawing, the system comprises a battery *A* which feeds the primary winding *B* of the ignition coil via the engine-driven contact breaker *C*, which is shunted by a condenser *D* to prevent sparking at the contact breaker. The secondary winding *E* is connected in parallel with the ignition condenser *F*, one end of which is connected to "earth" and to the outer electrode of the surface discharge sparking plugs *G*, while the other end is connected to the rotor arm *H* of a distributor, which rotates past the stationary distributor contacts *J* connected to the central electrodes of the sparking plugs *G*. The rotor arm of the distributor is constructed as a resilient arm, at the end of which is located the distributor contact *K*, which rotates past the fixed contacts at a short distance, which depends on the speed of rotation of the rotor arm. Thus if the arm rotates slowly, the distance between the contact *K* and the contact *J* will be greater than when the engine runs at high speed, owing to centrigugal force. The maximum deflection of the distributor arm *H* is limited by a fixed stop *L*. Modified designs are also shown in the specification.—*March* 9, 1955.

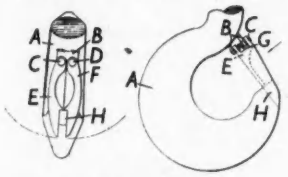


No. 725,619

CRANES AND LIFTING APPLIANCES

725,927. November 11, 1953.—IMPROVED HOOK FOR CRANES AND OTHER LIFTING APPARATUS, Reginald Cecil Parsons, 34, Partridge Road, Roath, Cardiff.

An object of the invention is to provide improved means for preventing a sling from being inadvertently displaced from the hook while a load is being carried. Referring to the drawings, a hook *A* has a bracket *B* at or near to the shank. The bracket supports two spaced pivot pins *C* and *D*, on which are mounted arms *E* and *F*. As shown, a spring *G* has one end engaged in the arm *E* and its other end in the bracket *B* the arrangement being such that the spring urges the arm *E* to its closed position. A similar spring is arranged to urge the arm *F* to its closed position. The pitch of the spring which biases the arm *E* is opposite to that of the spring which biases the arm *F*. The free end of each arm is shaped to lie against the tip *H* of the hook when the arm is in its closed position. The arms are preferably shaped to provide a finger opening between them when they are in their closed positions so that they can be moved apart easily when it is desired to place or remove a sling from the hook.—*March* 9, 1955.

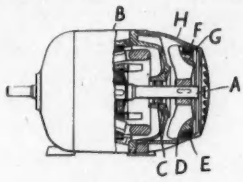


No. 725,927

POWER TRANSMISSION

725,588. March 20, 1953.—AXIALLY-OPERATED FRICTION BRAKE, Demag-Zug G.m.b.H., of Wetter/Ruhr, Germany.

The invention relates to a friction brake which is operated by the axial displacement of a part carrying one of its friction surfaces. The device is shown in the drawing fitted on an electric motor. On the elongated drive shaft *A* of an electric motor *B* having a displaceable armature, there is secured at an outer position beyond a bearing *C*, a friction disc *D*, which also operates as a brake. The rubber ring *E* is provided between the friction lining *F* and the friction disc and forms the support for the lining. The stationary friction ring *G* forms part of the motor housing *H*. Braking can be rendered particularly resilient by the friction lining *F* being formed of individual blocks or segments to compensate for small inaccuracies in the mounting and alignment of the friction disc. The free space between the segments also assists in the dissipation of the heat engendered by friction. The damping means may also be composed of individual sections divided into equal surface areas in order to improve the heat dissipating effect. Modified damping arrangements are also shown in the specification.—*March* 9, 1955.

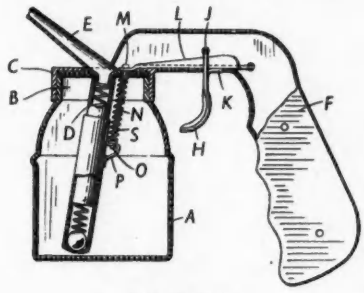


No. 725,588

TOOLS AND WORKSHOP APPLIANCES

725,769. July 20, 1953.—FORCE FEED OIL CANS, Joseph Kaye and Sons, Ltd., Lock Works, 84, South Accommodation Road, Hunslet, Leeds, 10, and Arthur Wainwright Kaye, of the company's address.

Referring to the drawing, the oil can body *A* has a filler opening *B* closed by a detachable cap *C*. The cap has secured to it the pump *D* with a delivery outlet *E* and the pistol-grip handle *F* carrying the trigger mechanism. The trigger mechanism comprises a trigger *H* pivotally mounted at its upper end *J*, which is forked, the cut away portion being bent at right angles to provide an actuating abutment *K* for a lever *L* pivoted at its rear end and extending forward between the forked end of the trigger to a position adjacent the pump *D*, the abutment acting on a point of the lever towards its pivoted end. The forward end of the lever *L* engages the enlarged head *M* of a rod *N*, which has a further enlarged end *O* supported in a slotted bracket *P* secured to the reciprocating cylinder of the pump *D*. A spring *S* supported by the rod *M* is mounted between the bracket *P* and the cap *C* for returning the lever *L* and cylinder *R* to their normal position when the trigger is released after the oil pumping movement.—*March* 9, 1955.

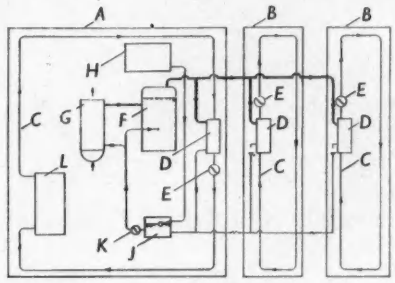


No. 725,769

RAILWAY ENGINEERING

725,669. January 23, 1953.—THE HEATING OF RAILCAR TRAILER ASSEMBLIES, Spanner Boilers, Ltd., 258, Brixton Hill, London, S.W.2. (*Inventor: Edward Frank Spanner.*)

In the drawing, *A* is a railcar and *B* are trailer cars forming an assembly of three vehicles. Each vehicle has a closed water heating system *C*, including pipes, a steam-heated calorifier *D* and a circulating pump *E*. In the railcar *E* is the ordinary pump for circulating cooling water through the jacket of the engine *L*, but in the trailers *B* the pumps are electrically driven. The calorifiers *D* are each supplied with steam from boilers *F* and/or *G* in the railcar *A* and discharge to the condensate tank *J*. The boiler *F* is of ordinary construction, fitted with an oil burner. The boiler *G* is an ordinary waste heat boiler of the kind adapted to act as a silencer for the diesel engine *L*. The boiler *G* is coupled to the boiler *F* below the water line so that the water is circulated through both the boilers by natural thermo-siphonic action, in some circumstances, in which case the boiler *G* is always full of water, whilst in other cases steam can be generated in boiler *G* and passed to the steam space of boiler *F*. Water is fed to the boiler *F* by the electrically-driven feed pump *K* supplied from the condensate tank *J* that is connected to a feed tank *H* at high level through a ballcock, the motor of the feed pump *K* being controlled by an electrical switch actuated by the water level in the boiler *F*. The radiator for the cooling water of the engine *L* is arranged so that it can be isolated by a by-pass controlled by a thermostatic valve and/or by a hand-operated control valve.—*March* 9, 1955.

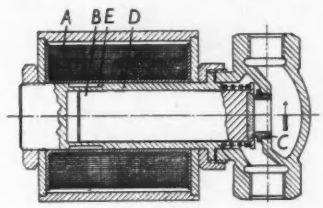


No. 725,669

VALVES

725,702. February 27, 1953.—SOLENOID ACTUATED VALVES, Erich Herion, Wildermuthweg 5/II, Stuttgart-W., Germany.

In the electromagnets described in this invention, which are in the form of solenoids used for the control of valves, the guide cylinder is made in one piece with no soldered or welded portions. Referring to the drawing, the coil is shown at *A* and the armature which serves to close or open the orifice through the valve seating *C* at *B*. The guide cylinder *D*, made of magnetically conductive material, is provided with an annular recess at a suitable position at *E*, whereby a displacement of the magnetic field is effected. By the appropriate selection of the cross section of the recess *E* the magnetic attraction characteristic can be adapted to suit each individual case. However, if required, the recess can be wholly or partly packed with, or reinforced by, a material which may advantageously be non-magnetic. It is thus possible to change the magnetic field to meet the specific purpose for which the solenoid-actuated valve is required.—*March* 9, 1955.

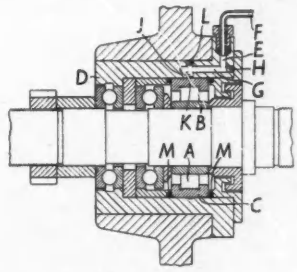


No. 725,702

BEARINGS AND SUPPORTS

725,738. May 11, 1953.—ADJUSTMENT OF THE CLEARANCE IN BEARINGS, Aktiebolaget Svenska Kullagerfabriken, 17, Artillerigatan, Göteborg, Sweden.

In the drawing the radial bearing *A*, which carries a spindle, is provided with an inner race ring *B*, which is a force fit on the spindle. The outer race ring *C* of the bearing is fitted in a housing *D* with a radial channel *E* connected to a pipe *F* through which is admitted the fluid pressure medium. A longitudinal channel *G* is connected to the channel *E* and is closed at its outer end by a plug *H*, but opens near its inner end into a radial channel *J*. This channel leads to an annular groove *K* in the bearing seat in the housing and is closed at its outer end by a plug *L*. Engaging the bearing seat at each side of the outer race ring *C* is a sealing ring *M* of rubber or plastic. Pressure fluid fed to the groove *K* exerts



No. 725,738

a pressure on the housing *D* and on the outer race ring *C* and is prevented from leaking out at the sides of the race ring by the sealing rings *M*. Since the race ring *C* has a substantially weaker section than the housing *D*, it becomes deformed to a greater extent by the fluid pressure than does the housing. The radial pressure on the ring results in a decrease in the clearance of the bearing *A*. By suitably adjusting the fluid pressure it is possible to obtain any bearing clearance required. The pressure medium employed is one which will harden after pressing—that is to say, will solidify after being forced between the annular member and its seat. Thus the bearing clearance will be adjusted for all times.—*March* 9, 1955.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1

RAILWAY TRACK SPANNERS

No. 2589 : 1955. Price 2s. 6d. This latest addition to the existing series of specifications for the various kinds of spanner in common use deals with spanners for the railway platelayer. For easy reference all specified dimensions are clearly shown on a series of sketches of the tools.

The sizes and types of spanners given in the specification relate to British Railways and do not necessarily apply to overseas systems.

REPORT ON PERMISSIBLE STRESSES IN CRANE STRUCTURES

No. 2573 : 1955. Price 4s. This new standard is published in an endeavour to secure a basis for crane design which will result in economy in the use of material, in accordance with the recommendations of the Steel Economy Committee of the Cabinet. Experiments are still in progress to verify these recommendations, but it is thought that the issue of an interim report will be of assistance.

The report advocates certain changes in the method of considering stresses in crane structures compared with the methods employed in existing British standards for cranes. Tables are given of basic stresses in certain specified materials—steel to B.S. 15, B.S. 548, and B.S. 968, and Grade 15 and Grade 20 tubes to B.S. 1775—which are related to the specified yield points of those materials. These basic stresses are used in determining the maximum permissible working stresses, which are also related to the kind of work to be performed by the crane and the number of hours in service per year. Cranes are classified on this basis, to enable the user to select the correct class of crane for the work required, and the crane maker to economise in the use of material and in cost of manufacture.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Thurs., April 21*st.*—MERSEYSIDE SECTION : Riversdale Technical College, Riversdale Road, Liverpool, 19, Annual General Meeting, followed by Technical Films, 7 p.m.

Wed., April 27*th.*—LONDON SECTION : School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, S.W.1, "Suppressed Aerials for the Aircraft H.F. Band," K. J. Coppin, 6.30 p.m.——S. WALES SECTION : Cardiff College of Technology, Cathays Park, Cardiff, "Some Technical Problems in Sound and Television Broadcasting," K. R. Sturley, 6.30 p.m.

CHADWICK PUBLIC LECTURE

Wed., April 20*th.*—Reardon Smith Lecture Theatre, National Museum of Wales, Park Place, Cardiff, "The Role of the Public Health Inspector," Neil R. Beattie, 3.30 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., April 26*th.*—Church Institute, Hull, Annual General Meeting, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Tues., April 19*th.*—SESSIONAL MEETING : Institution of Electrical Engineers, Savoy Place, London, W.C.2, "Electro-Luminescence," H. C. Bate and J. N. Bowtell, 6 p.m.

Wed., April 20*th.*—N. LANCASHIRE GROUP : N.W. Electricity Board, 19, Friargate, Preston, Annual General Meeting, 7.15 p.m.

Fri., April 22*nd.*—BATH AND BRISTOL CENTRE : Royal Hotel, Bristol, Annual General Meeting, 6.15 p.m.——BIRMINGHAM CENTRE : "Regent House," St. Phillip's Place, Colmore Row, Birmingham, "The Design and Application of Flameproof Lighting Equipment," D. A. Strachan, 6 p.m.

Mon., April 25*th.*—LEICESTER CENTRE : E. Midlands Electricity Board, Charles Street, Leicester, "Lamps and Lighting for Inspection," H. E. Bellchambers, 6 p.m.

INCORPORATED PLANT ENGINEERS

To-day, April 15*th.*—BIRMINGHAM MOBILE PLANT DISCUSSION GROUP : Imperial Hotel, Birmingham, "Fuel Injection and Lighting of Excavators," 7.30 p.m.

Mon., April 18*th.*—DUNDEE BRANCH : Mathers Hotel, Dundee, "The Factories Acts, 1937 and 1948, as They Affect the Plant Engineer," R. E. Griffith, 7.30 p.m.

Tues., April 19*th.*—S. WALES BRANCH : Mackworth Hotel, Swansea, "Incentive Bonus for Maintenance Work," A. J. Speakman, 7.15 p.m.

Wed., April 20*th.*—GLASGOW BRANCH : Scottish Building Centre, 425/427, Sauchiehall Street, Glasgow, "Industrial Electrical Installations," F. Jones, 7 p.m.——KENT BRANCH : Bull Hotel, Rochester, "Theory and Practice of Earthing Electrical Equipment," W. J. Jones, 7 p.m.

Thurs., April 21*st.*—MERSEYSIDE AND N. WALES BRANCH : Royal Institution, Colquitt Street, Liverpool, Chairman's Address, 7.15 p.m.——BLACKBURN BRANCH : Golden Lion Hotel, Blackburn, Brains Trust, Sir Oliver Lyle, E. G. Ritchie, A. L. Wallwork, Question Master E. Tyler, 7.30 p.m.

Mon., April 25*th.*—W. AND E. YORKSHIRE BRANCH : The University, Leeds, "Admiralty Salvage," W. D. Miller, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Tues., April 19*th.*—COVENTRY AND DISTRICT SECTION : Room A5, Technical College, Coventry, Annual General Meeting, followed by a Film Show, 7.30 p.m.——E. ANGLIAN SECTION : Central Hall, Public Library, Ipswich, Annual General Meeting, followed by Films, 7.30 p.m.

Sat., April 23*rd.*—LANCASHIRE BRANCH : Engineers' Club, Albert Square, Manchester, Annual General Meeting and Election of Officers, followed by John Wilkinson Memorial Medal Presentation and Winning Paper in the Short Paper Competition and "Foundry Brains Trust," 3 p.m.——W. RIDING OF YORKS. BRANCH : Technical College, Bradford, Annual General Meeting and Election of Officers, followed by Junior Prize Winning Award, 6.30 p.m.

INSTITUTE OF FUEL

Wed., April 20*th.*—N.W. SECTION : Engineers' Club, Albert Square, Manchester, Annual General Meeting, Visit of the President, W. Idris Jones, 2.15 p.m.

Thurs., April 21*st.*—E. MIDLAND SECTION : Gas Showrooms, Nottingham, Annual General Meeting, "Nuclear Power," J. Rotblat, 6.15 p.m.

INSTITUTE OF MARINE ENGINEERS

Tues., April 19*th.*—85, Minories, London, E.C.3, "Crankcase Explosions in Marine Engines," J. H. Burgoyne and D. M. Newitt, 5.30 p.m.

Mon., April 25*th.*—STUDENT LECTURE : 85, Minories, London, E.C.3, "Safety at Sea," Stewart Hogg, 6.30 p.m.

Tues., April 26*th.*—85, Minories, London, E.C.3, Annual General Meeting, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Thurs., April 21*st.*—LONDON CENTRE : Royal Society of Arts, John Adam Street, London, W.C.2, "Gas Turbines and Their Application to Road Transport," A. Enticknap, 6.30 p.m.

INSTITUTE OF WELDING

To-day, April 15*th.*—SHEFFIELD BRANCH : Grand Hotel, Sheffield, Annual General Meeting and Film Show, 7.15 p.m.

Wed., April 20*th.*—W. OF SCOTLAND BRANCH : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Annual General Meeting and Film Show, 7 p.m.

Thurs., April 21*st.*—N. LONDON BRANCH : B.W.R.A., 29, Park Crescent, London, W.1, Annual General Meeting, followed by a Technical Session, 7.30 p.m.

Fri., April 22*nd.*—BIRMINGHAM BRANCH : Midland Institute, Paradise Street, Birmingham, "High Frequency Heating," K. A. Zandstra, 7.30 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Tues., April 19*th.*—Institution of Electrical Engineers, Savoy Place, London, W.C.2, "The Relative Merits of Air and Water Cooling for Tractor Engines," H. Meyer, 2.15 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Sat., April 16*th.*—N.W. BRANCH : College of Technology, Manchester, "Researches into Factors Affecting the Performance of Electro-Precipitators," J. R. A. Lakey and W. Bostock, 3 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., April 19*th.*—MARITIME MEETING : Great George Street, Westminster, London, S.W.1, "Reconstruction of Quays on the River Great Ouse at King's Lynn," D. V. Buck, 5.30 p.m.

Tues., April 26*th.*—ORDINARY MEETING : Great George Street, Westminster, London, S.W.1, "Potentialities of the British Railways System as a Reserved Roadway System," T. I. Lloyd, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., April 18*th.*—INFORMAL MEETING : Savoy Place, London, W.C.2, Discussion on "Domestic Circuits and Protection Devices," opened by H. W. Swann, 5.30 p.m.——N.E. CENTRE : Royal Station Hotel, Newcastle upon Tyne, Annual General Meeting and Conversazione, 6.15 p.m.

Tues., April 19*th.*—MEASUREMENTS SECTION : Savoy Place, London, W.C.2, Discussion on "The Measurement of Impulse Voltages and Currents, with Special Reference to the Testing of Surge Diverters," opened by R. Davis, 5.30 p.m.——S.E. SCOTLAND SUB-CENTRE : Carlton Hotel, North Bridge, Edinburgh, "Problems of Hydro-Electric Design in Mixed Thermal-Hydro-Electric Systems," T. G. N. Haldane and P. L. Blackstone, 7 p.m.

Wed., April 20*th.*—RADIO SECTION : Savoy Place, London, W.C.2, "A Study of the Long-Term Emission Behaviour of an Oxide Cathode Valve. Part I : Emission Behaviour of an Oxide Cathode on a Platinum Core. Part II : Emission Behaviour of an Oxide Cathode on Passive and Active Nickel Cores," G. H. Metson, 5.30 p.m.

Thurs., April 21*st.*—ORDINARY MEETING : Savoy Place, London, W.C.2, Kelvin Lecture, "Transistor Physics," W. Shockley, 5.30 p.m.

Fri., April 22*nd.*—EDUCATION DISCUSSION CIRCLE : Savoy Place, London, W.C.2, Discussion on "Technical Training in N.W. Germany," opened by K. R. Sturley, 6 p.m.

Mon., April 25*th.*—LONDON STUDENTS' SECTION : Savoy Place, London, W.C.2, "The Training of Graduates," J. M. Armstrong, 6.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., April 19*th.*—39, Elmbank Crescent, Glasgow, Annual General Meeting, "The Measurement of Ship Screws," A. Silverleaf and H. C. Garlick, 7.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., April 20*th.*—Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "Operation and Running Maintenance of Locomotives on the Nigerian Railways," F. H. Jaekel, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, April 15*th.*—GENERAL MEETING, INDUSTRIAL ADMINISTRATION AND ENGINEERING PRODUCTION GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, "Surface Examination by Reflection Electron Microscopy," J. S. Halliday, 5.30 p.m.

Tues., April 19*th.*—S. WALES BRANCH : Mackworth Hotel, Swansea, "The Design and Construction of the Uskmouth Power Station," T. H. Wood, 6 p.m.

Wed., April 20*th.*—E. MIDLANDS BRANCH : The University, Nottingham, "Fatigue of Metals," J. A. Pope, 7.30 p.m.——SOUTHERN BRANCH : College of Technology, Portsmouth, "Some Factors in the Selection of Machinery for Cargo Liners," L. Baker, 7 p.m.

Thurs., April 21*st.*—MIDLAND BRANCH : James Watt Memorial Institute, Great Charles Street, Birmingham, "Some Factors in the Selection of Machinery for Cargo Liners," L. Baker, 6 p.m.

Fri., April 22*nd.*—1, Birdcage Walk, Westminster, London, S.W.1, "Fuel Consumption and the Speed of Railway Transport," A. Gilmour, "An Experimental Turbo-diesel Locomotive," F. L. Picard, followed by Discussion, 5.30 p.m.

INSTITUTION OF MINING AND METALLURGY

Thurs., April 21*st.*—GENERAL MEETING : Geological Society, Burlington House, Piccadilly, London, W.1, Papers for Discussion, "Separation of Copper, Nickel and Cobalt by Selective Reduction from Aqueous Solution," F. A. Schaufelberger and T. K. Roy ; "A Decade of Progress in Canadian Mining (1945–1954)—Part I," H. A. Graves, 5 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Wed., April 20*th.*—INFORMAL MEETING : Fourth Floor, Waterloo Bridge House, London, S.E.1, "Acceptance Testing of Auto Exchange Equipment," L. G. Tite, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, April 15*th.*—W. WALES SECTION : Central Library, Alexandra Road, Swansea, "Costing and Finance for Production," E. C. Sayers, 7.30 p.m.

Sat., April 16*th.*—PETERBOROUGH SECTION : Campbell Hotel, Bridge Street, Peterborough, Film, "Precise Measurement for Engineers," introduced by S. P. Poole, 7.30 p.m.

Mon., April 18*th.*—DERBY SECTION : Trongates Hotel, Trongate, Derby, "Birth of a Process : Production of Synthetic Alcohol," H. E. B. Young, 7 p.m.——1954 GEORGE BRAY MEMORIAL LECTURE : Reynolds Hall, College of Technology, Sackville Street, Manchester, "Engineering and Production Aspects of Synthetic Fibre Manufacture," Robert Douglas, 6.45 p.m.

Tues., April 19*th.*—OXFORD SECTION : Town Hall, Oxford, "A Different Way of Looking at Management," W. B. D. Brown, 7.15 p.m.——LUTON SECTION : Town Hall, Luton, "Cold Forming of Light Alloys," D. A. Barlow, 7.15 p.m.

Wed., April 20*th.*—BIRMINGHAM BRANCH : James Watt Memorial Institute, Great Charles Street, Birmingham, "The Development of Special Machines with Particular Reference to Unit Construction," T. W. Elkington, 7 p.m.——S. ESSEX SECTION : Mid-Essex Technical College, Chelmsford, "Higher Management's Approach to Work Study," J. E. Currie, 7.30 p.m.——WOLVERHAMPTON GRADUATE SECTION : Technical College, Wulfruna Street, Wolverhampton, "Recent Developments in Metal Machining," K. J. B. Wolfe, 7.30 p.m.

Thurs., April 21*st.*—LONDON SECTION : Royal Empire Society, Northumberland Avenue, London, W.C.2, "Electronics in Modern Industry," R. H. Booth, 7 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Mon., April 18*th.*—MERSEYSIDE SECTION : Bradford Hotel, Liverpool, Annual General Meeting, 6.30 p.m.——S. WALES AND MONMOUTHSHIRE SECTION : College of Technology, Cardiff, Annual General Meeting and Film Evening, 7.30 p.m.

Wed., April 20*th.*—SOUTHERN SECTION : Polygon Hotel, Southampton, Annual General Meeting and Film Evening, 7.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, April 15*th.*—ORDINARY MEETING : Pepys House, 14, Rochester Row, London, S.W.1, "The Design of Materials Used in, and the Manufacture of, Pick Steels for Pneumatic Picks," C. Hutchinson, 7 p.m.

Mon., April 18*th.*—SHEFFIELD AND DISTRICT SECTION : Livesey Clegg House, Sheffield, "The Organisation of an Engineering Company," F. Sargeant, 7.30 p.m.

Fri., April 22*nd.*—INFORMAL MEETING : Pepys House, 14, Rochester Row, London, S.W.1, "Some Preliminary Notes on the 'Electronic Brain' in the Automatic Factory," W. J. Kease, 7 p.m.

LIVERPOOL ENGINEERING SOCIETY

Wed., April 20*th.*—24, Dale Street, Liverpool, Annual General Meeting, 6 p.m.

MANCHESTER GEOLOGICAL AND MINING SOCIETY

Thurs., April 21*st.*—Mining and Technical College, Wigan, "The Burning of Slurry on Mechanical Stokers," F. B. Karthauser, 3.15 p.m.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, April 15*th.*—Mining Institute, Newcastle upon Tyne, "The New Gear-Cutting Establishment at Clydebank," W. McLaughlin, 6.15 p.m.

REINFORCED CONCRETE ASSOCIATION

Fri., April 22*nd.*—MIDLAND COUNTIES BRANCH : James Watt Memorial Institute, Great Charles Street, Birmingham, "Recent Developments in the Technique of Precasting Concrete Structures," J. A. Derrington, 6 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., April 19*th.*—SECTION LECTURE : 4, Hamilton Place, London, W.1, "Thermoelasticity," W. S. Hemp, 7 p.m.

Thurs., April 21*st.*—MAIN LECTURE : Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "Aeronautical Research in Sweden," K. O. Lundberg, 6 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Sat., April 16*th.*—The University, Sheffield, "Subtense Measurements," G. Hurst, 10.30 a.m.

Wed., April 20*th.*—GENERAL MEETING : 12, Great George Street, Westminster, London, S.W.1, "The Building Industry in Denmark," Aage Christensen, Erling Fredericksen and Bjorn Bindsley, 6 p.m.

ROYAL STATISTICAL SOCIETY

Wed., April 20*th.*—ORDINARY MEETING : London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1, "A Method of Labour Turnover Analysis," K. F. Lane and J. E. Andrew, 5.15 p.m.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS

Mon., April 18*th.*—Engineering Lecture Theatre, University Building, St. George's Square, Sheffield, Film Evening, 7.30 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Thurs., April 21*st.*—ROAD AND BUILDING MATERIALS GROUP : Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, Annual General Meeting, "Recent Progress in the Chemistry and Technique of Lime Production," N.U.S. Knibbs, 6 p.m.

WOMEN'S ENGINEERING SOCIETY

Wed., April 20*th.*—Hope House, Great Smith Street, London, S.W.1, "The Development of Bridges in the United States," Emory L. Kemp, 7 p.m.